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RECENT DEVELOPMENTS IN TECHNIQUES,
EQUIPMENT AND METHODS
FOR GROUNDWATER PROSPECTING

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NOTES

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RECENT DEVELOPMENTS IN TECHNIQUES, EQUIPMENT AND METHODS
FOR GROUNDWATER PROSPECTING

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GEOLOGY

1. Throughout Australia, the search for and location of groundwater supplies is primarily one for the geologist, his work being assisted and augmented by the geophysicist, the chemist, and the driller.
2. The basis of all geological work is regional mapping, which is usually undertaken on scales of one inch to one mile (1:63,360) or one inch to four miles. This is followed by more detailed local mapping of each small area of interest, using aerial photographs.
3. Rocks of Palaeozoic or greater age are generally dense and strongly folded, their capacity to yield usable water in worthwhile supply being intimately dependent on the rock type, local structure and jointing, rainfall and topographic relief. All these influences have to be studied in assessing the potential of a particular area, this being the task of the field geologist.
4. The rock type affects groundwater salinity in two ways; one being the direct effect of certain rock minerals and their weathered products in making salts available for solution, the other an indirect effect resulting from joint development, which limits the movement of the groundwater. Jointing is also a major factor in controlling supplies, the hard and competent rock types such as quartzite having a relatively open joint system permitting freer movement of water than do the softer argillaceous rocks such as slates and mudstones.
5. The attitude of folded beds controls the selection of drilling sites, as water wells in hard rocks usually are not drilled deeper than 400-450 feet. It also governs the topography, controlling the development and direction of stream systems which may provide local intake along the valley floors, and affecting the fraction of surface run-off from the slopes.
6. Rainfall is important, it being not uncommon to find that rocks which in a 40-50 inch rainfall area yield groundwater with a salinity

of less than 500 p.p.m. may in a 20-25 inch rainfall contain 7000 p.p.m. water or worse.

7. All these factors must be considered by the field geologist when selecting well sites.

8. In sedimentary basins when the rocks are usually younger than Palaeozoic, folding is much less well developed, outcrops are often confined to the marginal areas, and problems of structure interpretation are best solved by test drilling either in a grid pattern or along selected section lines.

9. Outcrop mapping and levelling is important, because outcrops and subcrops are the intake and outlet zones. It is common to find that the rocks were deposited under saline water conditions, and will retain this original salt water unless it can be replaced by fresh water intakes from surface run-off. Field work therefore includes fairly detailed mapping of the basin margins, and investigation of any possible intakes in the basin centres such as may be provided by sink-holes in a karst topography, or stream lines and swamps.

10. The next step is drilling, which yields strata samples for palaeontological examination to elucidate the stratigraphy, water samples from which isohaline maps are prepared, and water levels from which isopotential maps can be drawn. This is usually followed by the pump testing of selected bores to determine transmissibility of the aquifers. With all such information available, a complete picture of the basin can be arrived at, and its groundwater potential assessed.

11. Salinities are measured in two ways. The more general method is to collect water samples from pumped wells, and submit them for detailed chemical analysis in which the chloride, carbonate, sulphate, sodium, magnesium and calcium ions are determined, as well as more unusual ions when necessary.

SALINITY TESTING

12. The chemical methods used are those set out by the American Public Health Association.⁵ As a preliminary to full analysis, the Specific conductance is determined, as being a measurement of the salt concentration. The apparatus comprises a Philips conductivity bridge, which measures the specific conductance between the electrodes of a cell compartment from a Dionic water tester, used because the Dionic cell has movable electrodes adjustable for temperature. This instrument, which is calibrated against a large number of chemically analysed samples by plotting average concentration against specific conductance, is not precise, since it assumes a constant ratio of ions throughout all waters tested. In the majority of waters this can be assumed, and the determination of "approximate total salts" by means of conductance yields quite useful results.

13. For use in boreholes where samples cannot be collected, a simple electrical probe has been developed, having a built-in thermistor to compensate for temperature variations. This probe, which has a diameter of 1.5 cm, can be lowered into small spaces on a cable, an A.C.

⁵ American Public Health Assoc., Standard methods for the examination of water, sewage and industrial wastes, 10th Edition, New York (1955).

voltage being obtained from a hand-operated Megger unit. It has been found particularly valuable in boreholes penetrating layers of differing salinities, or where salt water is leaking through a hole in the casing and contaminating the main supply, or where saline waters overlie better quality waters which they contaminate by downward movement in the well.

DRILLING

14. Percussion drilling is widely used and needs no description. One recent innovation in technique, however, is the use of a sequestering agent, sodium hexametaphosphate, during the process of development of a screened bore. This substance is mechanically forced down the bore and out into the aquifer around the screen, and then left for some hours, after which the supply is developed. It has been found very effective in removing clay material from a sandy aquifer, and supplies can commonly be increased to five or ten times their original value.

15. A second material has been used successfully for the chemical grouting of unconsolidated water-charged sands which tend to "blow" during drilling. This is a proprietary water soluble mixture of two organic chemicals, acrylamide and NN' -methylenebisacrylamide, mixed in proportions that will polymerize to stiff gels from dilute aqueous solutions, the action being controlled by catalysts. One limitation to its use is the need to place the whole of a mixed batch within the established induction period since if unexpected delays occur during pumping, gelation may occur before placement is achieved. It has an advantage over cement grout in being capable of much quicker handling through the pump, so that lightweight equipment can be used. It has particular value in drill holes for sealing off inflowing water and for preventing caving of strata in uncased holes, as well as the recovery of lost circulation in diamond drilling.

ELECTRIC WELL LOGGING

16. The only logging methods which would appear to be of value to the water well driller are the conventional Electric Log and the Radiation Log. Electric logging is of use only in uncased wells. In principle, the log is plotted against depth, the curve on the left showing in millivolts the spontaneous potential (S.P.) of the beds traversed, while on the right side is a family of curves (usually three) showing their resistivity at different distances from the borehole, in ohms per square metre per metre.

17. Spontaneous potential results from two causes, both dependent on seepage of the filtrate from the mud or fluid in the bore into porous beds. The first cause is an electromotive force (e.m.f.) set up when an electrolyte passes through a semi-permeable membrane (the mud sheath on the well walls) into another of different concentration. The second is an e.m.f. set up at the interface of two electrolytes of different concentrations. Both e.m.f.'s are proportional to the log of the ratio of the concentrations and are of the same sign.

18. The S.P. curve will show strong indentations when almost fresh drilling fluid diffuses into a salt water aquifer; will remain unaffected opposite permeable beds; and show reverse movement when the formation water is fresher than the drilling fluid.

19. The resistivity curves on the right hand side of the logs are

produced by passing an electric current through the formation between an electrode on the logging device and the ground surface, measuring the drop in e.m.f. between the two electrodes. By using electrodes spaced at different distances from one another, the resistivity at different distances from the borehole can be measured, these distances usually being 16 inches, 64 inches and 10 to 18 feet.

20. Clays and shales are conductive, since the water absorbed in the clay-mineral faces has a large content of electrolytes, but marine shales are commonly slightly more conductive than fresh water shales. Salt water sands are highly conductive, but fresh water sands are not.

21. The electric log can be used, by correlating corresponding curve indentations in different wells, for structural interpretation. Folding, warping, and tilting of the aquifer can be determined, and increasing shaliness of the aquifer or the salinity of its water can be mapped. Ordinarily, salinities can be calculated if the porosities are known, but as the limits between good and barely potable water are at the limits of accuracy of the method, such quantitative work may have little value. It may have a use in the drawing of contours.

22. Where fresh and salt waters are separated by a thin shale band, electric logs from different wells can show whether it is continuous, or lenticular and unlikely to effect a real separation of the two. The slight difference in resistivity between marine and fresh water shales may enable marine incursions into the water bearing formation to be mapped and areas of poorer water avoided.

23. In such work a small sonde and light logging outfit can be hired in any country from an internationally known American firm which specializes in such equipment.

GAMMA-RAY LOGGING

24. In bores that are cased or dry, neutron logs and gamma-ray logs are needed. Both have been used in Australia.

25. The apparatus for gamma-ray logging consists of a gamma-ray detector which is lowered down the borehole on the end of an electrical cable. The detector is a crystal of activated sodium iodide, which emits flashes of light when bombarded by the gamma-rays. The light flashes are changed into electrical impulses by a photomultiplier tube, the impulses being amplified in the recording truck and applied to a chart recorder, which gives a continuous record of the rate at which impulses are produced. The curve on the paper chart, therefore, shows the quantity of gamma radiation reaching the detector as it is lowered down the hole, and provides a measure of the natural radioactivity of the strata through which the detector is passing.

26. As the radiation emitted by any radioactive substance fluctuates from one moment to another it has to be averaged over a period of a second or two so as to give a fair estimate of the amount of radioactivity. The electrical circuits are designed to do this automatically, but the consequence is that the detector has to be lowered slowly to give it a reasonable time opposite each rock bed. The longer the time-constant of the equipment, the more faithful is the log, but the slower is the rate at which the hole can be logged in order not to miss the thinner beds. A time-constant of one second and a logging speed of 40 feet per minute are often used.

27. The radioactivity of rocks is due mainly to their minute content of uranium and thorium, but potassium, which is usually present in substantial quantities, also contains a small amount of radioactive isotope. It has been found that shale is generally the most radioactive of all sedimentary rock, sandstone and limestone being usually less so. Although some sandstones, particularly those that contain phosphates, can be more radioactive than most shales, the high gamma-ray counts on the log of a sedimentary sequence can in general be ascribed to shale, and the lower counts to sandstone or limestone.

28. The Great Artesian Basin, comprising two-thirds of Queensland and parts of neighbouring States has been drilled extensively, but drillers' logs of the bores do not give a reliable picture of the subsurface geology. To aid further drilling, more information is needed on the configuration of the aquifers, and a programme of gamma-ray logging of some hundreds of bores is now being undertaken by the Bureau of Mineral Resources to provide this information. Although the Mesozoic sandstones and shales in the Great Artesian Basin are continuous over vast distances, the sandstones often occur as lenses, so correlation is difficult unless the bores are close together.

29. The logs obtained to date have been from widely-spaced bores, but some of them enable correlations to be made. FIGURE I shows a suggested correlation of six bores in a line 100 miles long within the shallow Sub-basin, a part of the Great Artesian Basin. The aquifers belong to the Cretaceous and Jurassic formations known as the Blythesdale and Bundamba Groups. Some of the zones have been tentatively assigned formation names on the basis of a general geological account of the area by Whitehouse.⁶

30. Zone A is the best marker, and shows a sharp decrease in radioactivity from that of the layer above it, followed by an increase corresponding to shale. Zone B is marked at the top by a decrease in radioactivity, indicating sandstone, below which are numerous "troughs" corresponding to sandstone beds. This zone is probably the top of the Gubberamunda Sandstone, one of the principal aquifers in the Blythesdale Group, and Zone A probably corresponds to part of the Fossil Wood Horizon, which is known to overlie the Gubberamunda Sandstone.

31. There are evidently several facies changes in Zone B between the Darrawong and Queen's Birthday bores, which may account for the lack of water production from this zone in the three northernmost bores. Zone B can be considered continuous only because of the correlation of Zones A and C. The logs serve to show that the water horizons themselves cannot be correlated over wide distances. In the absence of the logs, a considerable dip might have been expected between the Darrawong and Queen's Birthday bores.

32. However, according to the suggested correlation the rock dips are in fact quite gentle. In an area of steeper dips correlation would be more difficult; hence the need for logging bores close together.

33. From this work it is apparent that gamma-ray logs from a closely-spaced group of existing water bores can be used to give a sub-surface picture of the various sandstones, even though the holes are cased. The logs give no indication of the porosity of the sandstones or of their water-producing capacity.

⁶ Whitehouse, F.W., Artesian water supplies in Queensland: Appendix G - The geology of the Queensland portion of the Great Australian Artesian Basin, Govt. Printer, Brisbane, (1954).

THE NEUTRON MOISTURE METER

34. Since it was first reported^{7,8,9} about twelve years ago, that the water content of soil could be measured by a fast neutron scattering process, the apparatus required has been made in a form suitable for use in the field. Such portable apparatus may be purchased from perhaps ten manufacturers in several countries. Many users have made their own apparatus, according to the general layout shown in the block diagram in FIGURE II.

35. The probe houses a source of fast neutrons, which, after colliding with the protons of the soil water, diffuse back towards the probe as slow neutrons, there to be detected with a boron trifluoride counter tube. The circuitry is conventional, and employs proportional counting technique. The ~~gamma-ray~~ pulses associated with radium-beryllium neutron sources, must be rejected by the discriminator circuit.

36. Pulses caused by detection of slow neutrons are recorded, their rate of occurrence being proportional to the water content of the soil. The diameter of the probe is usually about 4 cm, and a number of investigators have described appropriate bore-hole installations. We prefer a bore-hole lined with black polythene tubing, 6.0 cm in outside diameter and having a wall thickness 0.48 cm¹⁰. Stolzy and Cahoon¹¹ discussed aluminium, steel and rigid plastic (P.V.C.) access tubes. The conclusion seems to be that aluminium or polythene access tubes should be preferred.

37. The volume of soil measured by the moderation of neutrons increases as the water content decreases. Its shape is approximately spherical, with diameter 40 cm at a water content 0.2 cc/cc. Mortier *et al.*¹² attempted to reduce, or control, the sample size and shape by shielding the counter tube, but their results and the work of others show that the sacrifice of counting rate for reduced sample volume is not worth while. In fact, a large sample size is often desirable.

38. Stone *et al.*¹³ investigated the accuracy of the results to be expected from the neutron method of measuring water content. The standard deviation of an observation was largely contributed by the random fluctuations of the radioactive phenomenon. It is usually possible to make a measurement with a coefficient of variation of 1% in about 1 minute.

39. There is no limit, in principle, to the depth to which the water content may be measured. In practice, the drilling of a suitable bore-hole is sometimes difficult, when gravel or stones occur as strata in the soil. There should be no gaps between the bore-hole lining and the soil, not only because water may fill such a gap, causing

⁷ Belcher, D.J., Cuykendall, T.R. and Sack, H.S., Civil Aeronautics Admin. U.S.A. Tech. Rep. No. 127 (1950).

⁸ Gardner, W.R., and Kirkham, D., Soil Sci., 73: 391-401 (1952).

⁹ Spinks, J.W.T., Lane, D.A., and Torchinsky, B.B., Canadian J. Technology, 29: 371-374 (1951).

¹⁰ Holmes, J.W., and Jenkinson, A.F., J. Agric. Engin. Res. 4: 100-109 (1959).

¹¹ Stolzy, L.H., and Cahoon, G.A., Proc. Soil Sci. Soc. Amer., 21: 571-575 (1957).

¹² Mortier, P., de Boodt, M., and de Leenheer, L., Zeit. f. Pflanzen. D'ingung Bod., 87: 244-250 (1959).

¹³ Stone, J.F., Shaw, R.H., and Kirkham, D., Proc. Soil Sci. Soc. Amer., 24: 435-438 (1960).

an anomalous reading, but also because an air gap will cause the counting rate to be lower than it should be. The counting rate depends upon the diameter of the cavity in which the probe is placed, and calibration of the apparatus must include specification of the kind of access hole employed.

40. The neutron moisture meter has been used to measure the water content of soil in a variety of experiments with an agronomic aim. For example, Denmead and Shaw (private communication) investigated the rate at which soil moisture could be supplied to the roots of corn plants, as a function of soil water content. Cahoon *et al.*¹⁴ measured the water content of soil mulched with wood shavings, compared it with a bare soil mulch, in citrus orchards, and showed little difference in the effectiveness of the mulch.

41. The technique is useful in the search for underground water supplies, by virtue of its ability to observe the deep infiltration of soil water through soil to the ground water table. It provides a method of assessing the recharge rate of ground-water aquifers, which may occur in permeable sediments. Nixon and Lawless¹⁵ showed that the roots of "brush" species extracted soil water to a depth of 5 m on a deep sandy soil, whereas the same soil, when denuded of vegetation, transmitted much more water to the water table. Another example of an application of the method in hydrology is our own work¹⁶ on infiltration of soil water in heathland soils, which will now, briefly, be described.

42. The soils investigated occur in the Upper South East of South Australia, within about 30 miles of the River Murray mouth. The profile has developed in deep sands, the relict dunes of former sea-beaches. The native vegetation, comprising Eucalyptus, Banksia, Xanthorrhoea and Casuarina species amongst many others in a heath-like community, has the ability to thrive, despite the very infertile soils and a summer drought lasting for about six months. Development of this land for pastures, by clearing and fertilizer application, was hindered by the lack of water. Groundwater occurs at about 13 m in the sands, but its quality is very variable. Our experiment intended to answer, amongst others, the question: how is the groundwater recharged?

43. Two sites were selected for study, one in a newly developed pasture of lucerne and annuals, the other in the native heath. A water-table observation bore at each site was incorporated in a grid of more than 100 observation bores. At each site, neutron moisture meter access tubes were drilled to a depth of 6 m. The soil water regime, during 1956 to 1958, was measured regularly. The result showed that infiltration of soil water to the water table was negligible under both heath and lucerne vegetation. An example of the employment of the soil water profile to make this decision is given in FIGURE III. Soil water evidently did not penetrate past a depth of 5 m - at Heath Site 3. The regime was not so unambiguous at some of the other sites, but the conclusion that the ground water was not recharged significantly by local infiltration of rainfall agreed also with water-table changes, which did not have an annual period. The whole investigation has been reported in three publications.^{16,17,18}

¹⁴Cahoon, G.A., Stolzy, L.H., and Morton, E.S. *Soil Sci.*, **92**: 202-206 (1961).

¹⁵Nixon, P.R., and Lawless, G.P., *J. Geophys. Res.*, **65**: 655-661 (1960).

¹⁶Holmes, J.W., *Aust. J. Agric. Res.*, **11**: 970-988 (1960).

¹⁷Driscoll, E.P.D., and Shepherd, R.G., South Australia Dept. of Mines, Rep. of Investigations No. 15 (1960).

¹⁸Luthin, J.N., and Holmes, J.W., *J. Geophys. Res.*, **65**: 1573-1575 (1960).

44. Since 1959, the neutron moisture meter has been used to measure the water content of large lysimeter tanks 2m diameter by 2.4m deep, with successful results. This work is proceeding at present, in the Mount Gambier district of South Australia.

SURFACE GEOPHYSICAL PROSPECTING

45. In several of the larger sedimentary basins, surface geophysical methods of exploration have been used as an aid to the determination of structure. The most important of these is seismic work, and field parties have already covered large areas in several States. In general the results have been well worth while, although in places anomalies have occurred which have rendered interpretation difficult. In some instances, it has proved not possible to distinguish between Tertiary and Mesozoic sediments and the underlying Palaeozoic basement rocks. Despite the considerable expense involved, the Bureau of Mineral Resources and the South Australian Department of Mines are maintaining parties in the field, investigating several areas.

46. Electrical resistivity work, which has a limited application as regards depth, has not proved effective. In some areas it has been found impossible to distinguish between sands and shales at depths of less than 200 feet from the surface, even when the sands were water charged. In the Adelaide Plains in South Australia, the existence of a thin saline soil layer completely blanketed the underlying beds and no results were obtainable at all. Electrical resistivity methods appear to have little or no application to sedimentary stratigraphic investigations, at least in some parts of Australia, from a groundwater viewpoint.

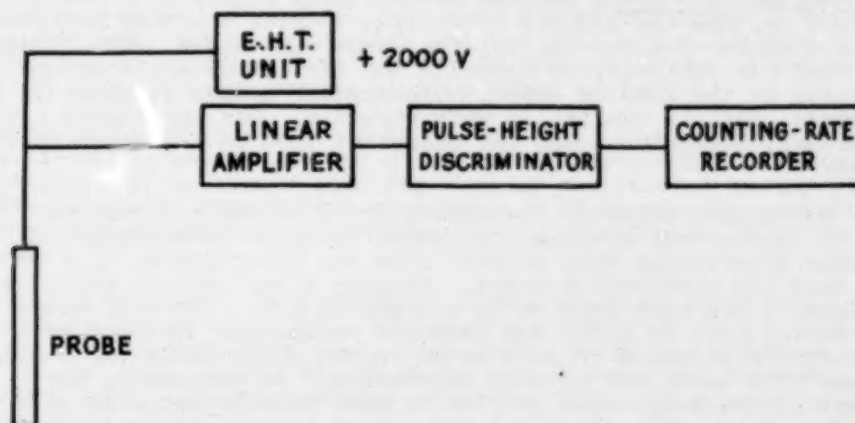
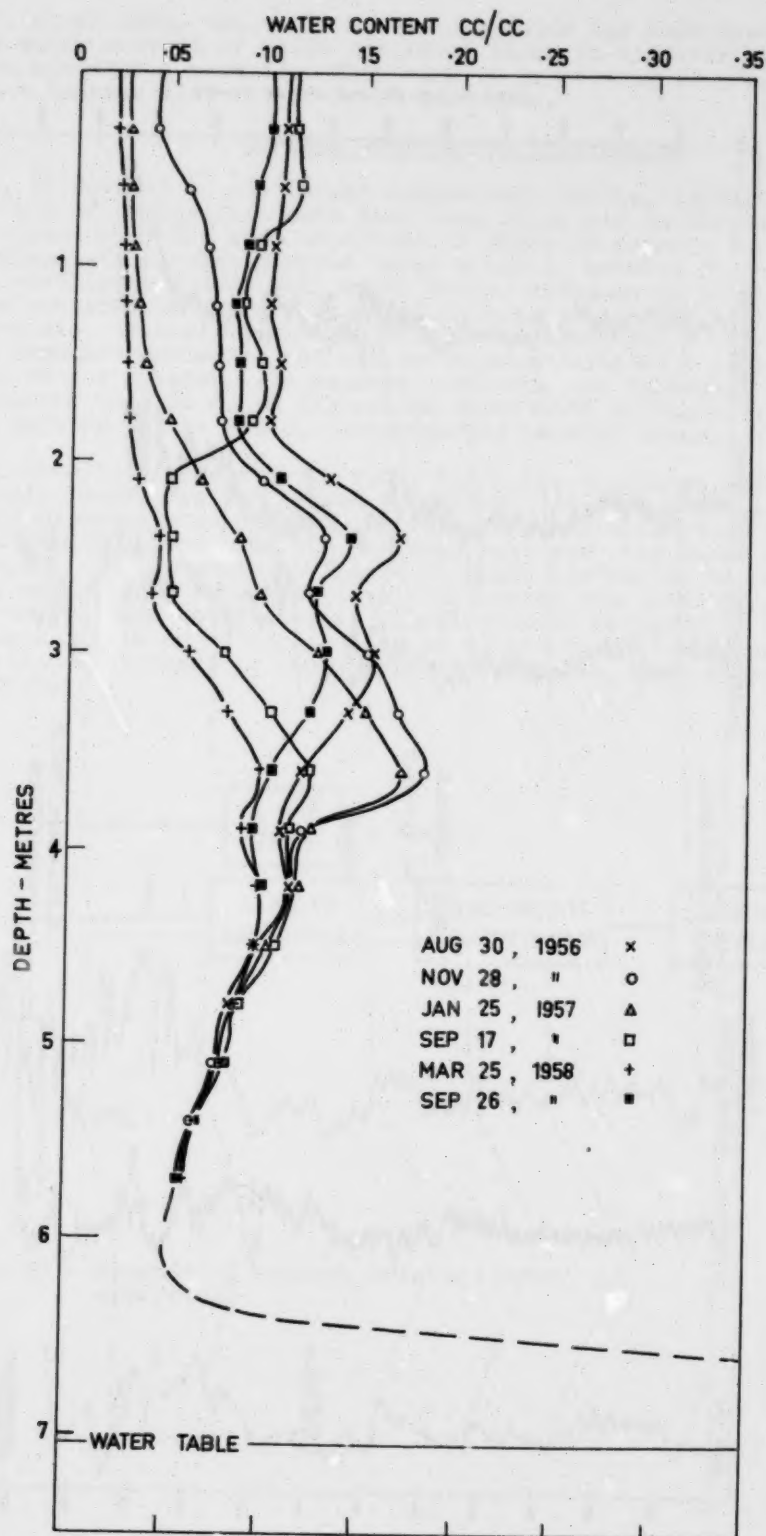


FIG. II - Diagram of neutron moisture meter apparatus.

Fig. 1



FIG. 1



Left: FIG. III - Water content profiles - Heath site No.3.



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The contributor Government notifies the following correction :

page 3, paragraph 18, line 3 :

instead of :

"Permeable"

read :

"Impermeable".



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Agenda Item : A.5.1

India

EXPLORATION METHODS

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EXPLORATION METHODS

by

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INTRODUCTION

Scope and purpose

1. Mineral deposits are rare. They are concentrated forms of wealth. The search for them in the past was often of the nature of a private treasure hunt. The position has radically changed. Mineral exploration programmes are now directed towards developing the potential mineral wealth of the region to the maximum extent possible, to provide the necessary mineral raw material base for industrialisation and to make significant contributions to the national economy through foreign exchange savings/earnings. In relation to this larger objective, scientific systematic, integrated programmes of exploration are of far greater significance than a random search for buried treasure.
2. The purpose of this article is to discuss the various factors which are relevant in drawing up appropriate programmes of mineral exploration and the advantages to be derived through proper integration.
3. The recent developments in mineral exploration in India are briefly described as an illustration of an integrated mineral exploration programme under implementation, which is related to the available opportunities and the specific needs of the country.
4. The need and scope for international cooperation in the field of mineral exploration is briefly discussed.

Need for mineral exploration in the under developed countries.

5. The major compelling reasons in favour of mineral exploration programmes in under-developed countries may be listed as under:-
 - (a) Mineral development is of crucial significance in bringing about rapid increases in gross annual income.
 - (b) The basic solution to the problem of poverty in under-developed areas is accelerated development in the fields of agriculture, transport, power and heavy industries. All these are large consumers of mineral raw materials.
 - (c) Low rate of capital formation is a major bottleneck to development in such areas and investments capable of yielding large and rapid returns are very much to be favoured. Well conceived programmes of mineral exploration under favourable conditions meet these requirements.

- (d) Minerals, being commodities in international commerce, are important as foreign exchange earners/savers and basis for barter.
- (e) Mineral development often acts as a catalyst of general economic development.
- (f) Mineral exploration in under developed countries is not merely a national but an international necessity as no country is self sufficient in all minerals. And again rapid depletion of mineral resources is taking place in advanced countries because of intensive exploitation. From the long range point of view, the requirements of mineral raw materials for industries in these countries will have to be met increasingly from new discoveries in under developed countries.

q LIMITING FACTORS IN THE DETERMINATION OF AVAILABLE EXPLORATION OPPORTUNITIES.

6. Well-conceived mineral exploration programmes should be based on scientific anticipations of the available exploration opportunities. There should be adequate recognition of the factors which limit exploration opportunities in a region.

Geological factors

7. The available exploration opportunities in a region are determined in a fundamental way by the geology of the terrain. The relevance of the geological factors to mineral exploration programmes at the planning stage, would consist of demarcating areas of potential interest with respect to various minerals. Apart from broad regional anticipations on the basis of geology of the terrain, specific information with respect to mineral occurrence may be available. Such information would naturally provide a sound basis for estimating exploration opportunities.

Other factors

8. The location of a deposit with respect to its accessibility, availability of transport facilities, labour, power and markets, etc., is a determining factor in its minability. Little useful purpose will be served by exploration of mineral deposits in locations, which will render the deposits unminable. What constitutes minable ore is determined by general and local technological conditions. For practical purposes, exploration opportunities are represented only by such deposits as hold out promise of proving minable under the relevant technological conditions.

Exploration opportunities not static

9. Exploration opportunities, however, are not static. New prospects come to light with progress in exploration. Technological developments may bring what was formerly marginal or sub-marginal grade to within the minable grade. General industrial development creates increased demands for mineral raw materials and thus improves the marketability of ore won from a deposit. Exploration programmes, therefore, must be based on a constant review of available exploration opportunities.

A CRITICAL SURVEY OF THE SCOPE AND LIMITATIONS OF DIFFERENT METHODS OF EXPLORATION WITH SPECIAL REFERENCE TO GEOPHYSICAL, GEOCHEMICAL AND PHOTO-GEOLOGICAL METHODS.

10. The ultimate objective of mineral exploration is the exploitation of the mineral wealth. This objective cannot be realised at one bound. Mineral deposits are rare and for the purpose of exploitation, very detailed information, obtainable only through intensive exploratory and proving operations, involving considerable expenditure of time and money, is necessary. Such intensive operations can

only be justified in selected promising prospects. The problem in mineral exploration, therefore, is essentially one of narrowing down the field of operations through successive stages in the exploration programme, and finally carrying out intensive exploration and proving operations in individual prospects for the purpose of converting them into working mines.

11. The whole gamut of activities relating to the acquisition of knowledge essential for exploitation of mineral wealth constitutes mineral exploration. These activities can be conveniently divided into a number of stages. These are -

- (i) Regional reconnaissance surveys.
- (ii) Detailed investigations of mineralised districts.
- (iii) Preliminary appraisal of new prospects.
- (iv) Detailed exploration and proving operations in selected prospects.

12. The different methods in exploration have all a common objective, namely, the discovery of minable ore bodies or mineral deposits and obtaining all the data essential for planning their exploitation although their scope and limitations are different at the different stages. The exploration methods can be conveniently classified into the following groups:

- (a) Field geological methods.
- (b) Photo geological methods.
- (c) Geophysical methods.
- (d) Geochemical methods.
- (e) Drilling and exploratory mining.
- (f) Laboratory investigations.

13. The scope and limitations of the different methods can be most significantly discussed in relation to different stages in exploration.

14. The main objective at this stage is to obtain, as quickly as possible, a broad picture of the regional geology, so that the available areas, worthy of more detailed investigation, can be demarcated. The location of individual prospects has to be regarded only as an incidental opportunity that may be taken advantage of. The extent to which this work is essential, before more advanced stages of exploration can be initiated, will depend on the information already available. In completely virgin areas, for which even topographical maps are not available, aerial photography and aerial photogeology are ideally suited. Ground geological work cannot be totally eliminated, since the effectiveness of photo interpretation will depend, to a great extent, on the control data available from ground geological investigations. Generally speaking, even geophysical methods employing airborne instruments will not be applicable at this stage. Geochemical investigations could be undertaken as an adjunct to ground geological investigations. The question of employing drilling and mining at this stage does not arise. The scope and limitations of photo-geological methods vis-a-vis ground geological methods merit the most serious consideration in this connection.

15. The major advantages of photo-geology may be briefly stated as follows:

- (a) The slow and more expensive ground geological investigations may be confined to critical areas.
- (b) The selection of critical areas in advance is likely to lead to successful results in mineral exploration, earlier than can be otherwise expected.
- (d) By limiting the areas for ground examination, the services of really competent and experienced geologists could be more effectively utilised.

- (d) The delineation of rock outcrops would result in a great reduction in the time and energy spent in mapping, by limiting ground examination, only to areas where such examination is feasible.
- (e) Supervision of ground geological work is possible only by going over the ground. Whereas, photo-geological interpretation can be easily checked by a more experienced person by re-examination of the photographs.
- (f) The regional geological picture would require constant review, in the light of additional data collected in the course of detailed investigations. Such re-views would be easy to carry out through photo-geological interpretation, whereas in the absence of photographs actual ground work will be necessary.
- (g) The photograph is an objective and detailed reproduction of all features which can find an expression in it. There is no personal bias in elimination or selection of details. In actual ground mapping, at the reconnaissance stage, a feature not considered significant, would not receive attention. Such a feature may turn out to be extremely important from the point of view of search for ore. The only way of working out the regional implications of the significant feature, in the absence of photographs, would be going over the ground once again. On the photographs, repetitions of the same feature can be readily interpreted, with little expenditure of time and money.
- (h) Even a thin cover would prevent ground geological examination, but this would not stand in the way of photo-geological interpretation.
- (i) Where the ground is covered by a thick canopy of trees, it may be almost impossible to do any ground geological work. Photogeology, on the other hand, which relies essentially on morphological expression on geological features, would be able to give significant pointers for mineral search, even under such conditions.

16. Photo-geological methods have a number of limitations. Photo interpretation is based essentially on the study of morphology, tone, texture and linears which show up on the photographs. The geology of a region to the extent it is reflected in recognisable features on the photographs can be interpreted through photo-geological studies. The contacts between different formations and rock types can be traced, faults, fractures, joint patterns, etc. can be identified and areas where rock exposures may be expected, can be demarcated. The approximate depth of soil cover can be estimated. Vital information, such as, the actual nature of the rock type, their mineral composition, the fossil contents of beds, etc., cannot be obtained.

17. To sum up, photo-geological methods without adequate ground control, may yield results of little practical significance; but with adequate ground control, they can greatly accelerate the progress of mineral exploration programmes.

18. Geochemical investigations are ground methods and can be conveniently carried out along with the ground geological work. Geochemical sampling results, at this stage, may help in the location of likely mineralised districts, as well as the elements which may be expected to be found in the district. Apart from this possibility, it is being increasingly recognised that geochemical data are of fundamental significance in the understanding of the geology of an area, in relation to economic mineralisation. It is best to build up a geochemical map right from the early stages.

Detailed investigation of mineralised districts

19. On the basis of the regional geological picture, the likely mineralised districts would have been already delineated. In the next stage, the detailed

investigation of the mineralised districts would be commenced. The ground geological methods would become essential at this stage. The mapping will be on a larger scale (1:10,000) and would be specially oriented in relation to the types of mineralisation which are being looked for. Detailed investigations for oil, coal, iron ore, base metals, precious metals, etc. would all call for specialised procedures at this stage. The mapping may still be done on large scale aerial photographs, the geology being subsequently transferred to toposheets by means of a sketchmaster. Photo-geological interpretation would play a small role directly. It may, however, still play an important role indirectly. Any important feature recognised on the ground, which finds expression on the photographs, may be interpreted by photo-geology over the entire district, so that critical attention may be given to such areas. Geophysical and geochemical methods will begin to play an increasingly important role. The scope and limitations of the geophysical and geochemical methods may be briefly considered in this connection.

20. Geophysical methods are indirect methods, which attempt the detection of geophysical anomalies. The chief methods are seismic (refraction and reflection), gravity, magnetic, electro-magnetic, electrical and radio-active. The methods can be used singly or in combination. The seismic and gravity methods have great depth penetration and are valuable where structure is an important localising factor in mineralisation, as in the case of oil. They are relatively more expensive and are ground methods. The magnetic, electro-magnetic and radio-active methods are comparatively cheaper and are also capable of being employed in aerial surveys.

21. The presence of a geophysical anomaly by itself does not indicate the presence of a mineral deposit. In the search for iron ore, for instance, a strong anomaly may be obtained for a magnetite bearing quartzite, while no anomaly may be found for a large hematite ore body. Where a problem in mineral exploration is geologically defined and indicated as capable of geophysical exploration, the use of geophysical methods can give extremely valuable results. In the case of concealed ore bodies, where geophysical investigations are applicable, they should always be tried before resorting to the more expensive methods of drilling and exploratory mining. Areas suggested by photo-geological interpretation can be geophysically surveyed prior to detailed investigation.

22. Geochemical investigations have a fundamental significance in the understanding of the geology of an area and are also proving increasingly useful in the exploration of mineral deposits. They have found wide application in the exploration for oil as well as for a variety of metals. The major developments are related to improvements in analytical techniques. The improvements in analytical methods have been in two directions - (i) Increase in accuracy and (ii) Increase in the rate of routine analyses.

23. The geochemical cycles for a number of elements are being worked out and the results show a very significant relationship between the geochemical cycle of elements and deep-seated geological processes, such as tectonism, metamorphism, igneous activity etc. as well as near surface geological processes such as, weathering, erosion, sedimentation etc.

24. Geochemical methods are directed towards the recognition of dispersion halos of elements, but the significance of the halos in relation to the prospects of finding ore can be determined only by a critical study of the geochemical data in relation to the geological data. The cumulative weight of geochemical data over an entire region is likely to prove of greater practical significance than random localised investigations. The practice in the Soviet Union of preparing geochemical maps, along with geological maps is likely to obtain wider currency.

25. An attempt should be made to apply the principle of converging evidence. Geological, geophysical and geochemical investigations should be carried out and in the light of the results obtained, more detailed exploration should be undertaken.

Preliminary appraisal of prospects.

26. Preliminary appraisals will have to be carried out in selected prospects to determine (a) whether detailed proving operations are justified in the deposit; and (b) if so, the character and extent of the exploratory work considered necessary.

27. In arriving at a conclusion with respect to (a), the considerations to be kept in view are the following:-

- (i) The prospects of reaching a positive conclusion.
- (ii) The minimum and maximum prospects which can be foreseen on the available evidence.
- (iii) The relative merits of the prospects as compared to other known prospects.
- (iv) Is the localisation of ore in the deposit sufficiently well-understood to render detailed exploration immediately practicable.

28. In the preliminary appraisal, the principle of calculated risk as well as the principle of the weakest link must be kept in view. While geological considerations alone would have received attention at the early stages, from the initial appraisal onwards, mining considerations must be given equal weight.

29. All the data collected through detailed geological investigations, geophysical and geochemical investigations have to be critically examined before reaching conclusions on the points listed above. Once it is decided to select a prospect for detailed proving operations, the nature and extent of the exploratory work to be carried out will have to be determined. In certain cases, especially in sedimentary deposits the entire programme may be visualised in outline right from the start. In the case of lode deposits, this would not often be possible. An initial programme has to be drawn up on the results of which the nature and extent of further work to be carried out, will be decided.

Detailed exploration and proving operations in selected prospects.

30. Detailed geological investigations, drilling and exploratory mining constitute the chief methods in this stage. These operations are of an intensive character directed towards the obtaining of conclusive evidence essential for taking the decisions with respect to the major investment involved in exploitation as well as the collecting of the relevant data essential for proper planning of the exploitation of the deposit. Geological investigations are necessary for the purpose of guiding drilling and exploratory mining operations and for interpreting the data resulting from them. Detailed surface investigations including preparation of large scale contour geological plans, shallow pitting and trenching have the great advantage of being both rapid and cheap and maximum advantage should be taken of data obtainable in this manner. Under ideal conditions, such investigations can provide comprehensive, accurate quantitative data, which can form the main basis of appraisal. This is often the case with deposits of coal, iron ore, limestone, manganese, gypsum etc., where quarriable reserves are to be assessed.

31. For a variety of reasons such as, paucity of exposures, existence of minable ore at depths not reachable by pits and trenches etc., it is often necessary to supplement the near surface data with bore hole evidence, and data from exploratory mining.

32. The major problems in the integration of methods at this stage would consist of determining the relative extent to which different methods have to be employed. In some cases, estimates of reserves and grade of ore may be made on the basis of surface evidence coupled with bore hole data. In the case of lode deposits exploratory mining is often an inescapable part of the proving operations. A decision in this regard can be taken only after the localisation of the ore is properly understood. Since exploratory mining is time consuming, an attempt has to be made to start it as early as possible. There is, therefore, necessity to plan the surface examination and drilling operations in such a way as to enable a quick choice to be made of the ground where exploratory mining has to be carried out. In planning exploratory mining, the possibility of making it a part of development for exploitation should be kept in mind.

33. Geo-physical logging of bore holes can be carried out for purposes of correlation as well as for guiding the exploratory operations. Geo-Chemical determination of core and sludge samples can be carried out for investigation of the dispersion halos in depth.

NEED FOR SCIENTIFIC, PLANNED AND INTEGRATED PROGRAMMES OF EXPLORATION

Role of science vis-a-vis risks and opportunities in exploration

34. The risks involved as well as the opportunities available in mineral exploration are great. Instances are not rare where over a thousand million rupees have been spent in exploration for oil without resulting in the discovery of any commercially exploitable pool of oil. There have been many costly failures in the search for deposits of precious and base metals in different parts of the world. Mineral exploration, where successful, however results in enormous returns in relation to the investment involved. The Kuwait oil field yields in terms of royalties alone \$55 million annually. The Butte, Montana, copper deposit alone has yielded over 2.5 billion dollars worth of metal. The Kolar gold-field has produced around 2000 million of rupees worth of gold.

35. Mineral exploration in the past had been, for the most part, a random uncoordinated effort by individuals with little or no scientific background. Scientific exploration is now a necessity for a variety of reasons. Mineral development is essential for industrial development and has to keep pace with it. It can not any longer depend on the slow and uncertain results of random search. The great variety of mineral raw materials required by industry do not all lend themselves to the simple and primitive methods of search. Mechanised mining of low grade ore involves large capital investment and such investment cannot be made unless sufficient reserves, capable of amortising the capital, are proved in advance and all the data essential for the planning and execution of the project are collected. Rich, readily recognisable prospects are relatively few, and random methods of search are capable of developing only a small part of the overall mineral potentiality of a region.

36. The Broad strategy of mineral exploration consists of narrowing down the field of operation through successive stages in the exploration programme and finally concentrating detailed proving activities in selected prospects and thereby convert them into working mines. Valuable opportunities should not be missed and unwarranted risks should not be taken. A long, dark and difficult path has to be trod before the mineral potentiality of a region is converted into mineral production. To make the journey swift and secure, the light of science is essential.

The essentials of an integrated programme of exploration

37. Programmes of exploration have to be properly integrated to ensure the maximum results in minimum time at minimum cost. The integration has to take account of the specific needs for mineral exploration of the region under consideration, the available mineral exploration opportunities in the region, and the scope

and limitations of different methods of exploration at different stages of exploration.

38. Apart from integrating the different methods of exploration at the different stages, it is essential to look upon the different stages in exploration as parts of the broad strategy of mineral exploration of the region. In the course of detailed investigations of mineralised districts, the relative importance of various favourable features would be more accurately determined and certain new features, whose significance was not appreciated in the course of regional reconnaissance survey, might turn out to be extremely useful in the search for ore. The regional survey maps must be reviewed in the light of the new evidence and fresh demarcations of mineralised districts carried out. Preliminary appraisals of prospects might indicate features of interest in the recognition of prospects, which might have escaped notice earlier. The mineralised districts may require to be gone over in the light of fresh data.

39. Every mineralised district has distinct features and patterns of mineralisation. General geological theory can only indicate what can happen; but what indeed happens in a particular district has to be ascertained through detailed critical studies of data available from the different stages in exploration as well as from working mines. Detailed exploratory and proving operations can be undertaken only where there are prospects of finding minable ore. Exploitation is undertaken for the purpose of winning ore. Yet data obtainable as a result of these two activities, are of critical research significance in the science of ore search and appraisal with special reference to specific mineralised districts.

RECENT DEVELOPMENTS IN MINERAL EXPLORATION IN INDIA.

40. Revolutionary changes have taken place in the purpose, scope, tempo and nature of mineral exploration in India subsequent to 1947 when the country became independent. In many directions, in this field, what has been accomplished in the short span of 15 years subsequent to that date, exceeds in volume and variety what was achieved in the previous 100 years.

41. In the field of mineral exploration the role of the Geological Survey of India relates to the preparation of basic geological maps and the regional investigations of mineralised districts. In this connection, in addition to conventional geological methods, photogeological, geo-chemical and geo-physical methods are employed. Ground mapping on aerial photographs in a number of mineralised districts, such as the Zawar lead-zinc district, the Khetri and Dariba Copper districts and the Singhbhum copper belt have been carried out. The geo-physical surveys, employing seismic, gravimetric, magnetic and electrical methods have been carried out to locate favourable structures for oil as well as in connection with exploration of concealed deposits in a variety of minerals including copper lead, graphite, pyrites, diamond, etc. The geo-chemical investigations have been comparatively limited in scope and have not been directed towards the preparation of geo-chemical maps of the region. So far, they have been of the nature of testing out the different geo-chemical methods for the purpose of calibration in known mineralised areas, and for locating concealed extensions of known mineralised ground.

42. The Indian Bureau of Mines came into existence only in 1948 and its total strength consisted of a Director and two officers and the functions were limited to acting as an advisory body to the Government. To-day it has a total strength of around 150 officers and the scope of activities embrace a variety of functions including the introduction of scientific methods of prospecting, exploration, mining and utilisation of minerals through the systematic and regular inspection of mines, carrying out detailed exploratory and proving operations to convert prospects into workings mines; conducting research investigations in the field of mineral beneficiation and mineral technology; and the collection, collation and interpretation of statistical data relating to all aspects of India's mineral industry, such as

production, consumption, marketing, import, export, reserves and grade, utilisation etc.

43. A few of the important results of detailed exploratory and proving operations carried out by the Indian Bureau of Mines are given below:-

<u>Mineral</u>				<u>Reserves proved</u>
a)	<u>Coal</u>	..	..	1577.8 million tonnes
b)	<u>Iron-ore</u>	..	..	491.1 million tonnes
c)	<u>Limestone and dolomite</u>	..	..	88.6 million tonnes 10.2 million tonnes
d)	<u>Copper Ore</u>	..	..	100 million tonnes average grade 1% Cu
e)	<u>Copper-lead-zinc</u>	..	..	0.36 million tonnes, Total metal content 6.24%
f)	<u>Pyrites</u>	..	..	76.2 million tonnes, Sulphur content 40%
				Indicated reserve - 313.9 Million tonnes.
g)	<u>Magnesite</u>	..	..	12.19 million tonnes, containing about 41 to 46% magnesia.

44. The basic approach of the department has been not to limit the objective of proving operations to the narrow purpose of finding ore in individual prospects but to regard the entire exploration and proving operations as a major programme of scientific investigation involving the application of the test of predictability. The result is that a constantly growing body of scientific knowledge of great practical significance to mineral exploration in different mineralised districts of the country is being created and full advantage is being taken of the cumulative value of this knowledge in the execution of fresh items in the programmes of mineral exploration.

45. While the latest techniques in mineral exploration such as, geochemical prospecting, geo-physical prospecting and aerial survey, etc., are extremely valuable aids in mineral exploration, India has a peculiar national asset, namely, a long tradition of civilised life, which is reflected in the shape of numerous old workings for gold, copper, lead, zinc, silver, etc. in different parts of the country. The old workings, provide a wealth of data, which have proved of immense help in the search for ore by the Indian Bureau of Mines.

46. Recently a scheme of rewards to private parties bringing to the notice of the government mineral finds of economic importance has been instituted which will ensure that even laymen play their role in the extensive search for mineral prospects.

47. A separate Oil and Natural Gas Commission has been set up to carry out oil exploration on a major scale in the country. In addition to the conventional methods, latest methods in exploration for oil are employed by the Commission including aeromagnetic surveys, geo-physical surveys and photo-geological surveys. Notable success has already been achieved in the Cambay and other areas in Gujarat.

48. The department of Atomic Energy is carrying out extensive radio-metric surveys, both on the ground and by air, in their search for deposits of radio-active minerals.

49. A significant amount of mineral exploration is being done by the private sector as well. Introduction of scientific methods of prospecting and exploration in the private sector is the responsibility of the MC & CM Division of the Indian Bureau of Mines. Tata Iron & Steel Co. Ltd have their own prospecting organisation.

50. In relation to the country's needs, as well as potential mineral wealth, a vast increase in mineral exploration activity in all stages, including regional investigations, detailed investigations, of mineralised districts and detailed exploratory and proving operations in selected prospects, is justified. India is an example of an under-developed country, where planned, scientific and integrated mineral exploration programmes are being implemented, employing both the conventional methods as well as the new ones, such as, photo-geological, geochemical and geo-physical methods.

THE SCOPE AND NEED FOR INTERNATIONAL CO-OPERATION IN THE FIELD OF MINERAL EXPLORATION

51. There is a great scope as well as a need for international co-operation in the field of mineral exploration. The mineral requirements of the world will have to be increasingly met from under-developed countries, as deposits in the more advanced countries get exhausted by intensive exploitation. In the exploration of the under-developed areas, the technical and scientific resources in the possession of the advanced countries would require to be employed. As exploration programmes begin to meet with success in under-developed countries, a position of imbalance with respect to raw material resources and plant capacity is likely to ensue. In other words, under-developed countries may have an excess of mineral raw material resources, while the advanced countries will have an excess of plant capacity. Thus a world economy can be built by effecting the necessary adjustments through co-operation and goodwill. From the long range point of view, the advanced countries have an important stake in accelerating the pace of mineral exploration in under-developed countries. The various directions in which international co-operation is desirable as well as the scope for such co-operation, are briefly indicated below:-

52. Exchange of information:- The results of the considerable amount of work mainly being carried out in the Soviet Union are not easily accessible to those who do not know Russian. It would be a very great help if an annotated bibliography of all scientific work carried out in the Soviet Union in the field of mineral exploration is made available in English and translations of the original papers can be obtained on specific request. If a directory of all specialists holding responsible positions in mineral exploration programmes in different countries of the world is prepared, along with brief information indicating their areas of interest, it may greatly facilitate direct correspondence and discussion among specialists working on the same problems in different parts of the world.

53. Exchange and deputation of personnel:- A varied field experience is an extremely valuable asset to any one engaged in mineral exploration. Exchange and deputation of personnel is a very effective means of providing an opportunity for the acquisition of such varied experience.

54. Exchange of samples:- It is not possible for any individual to see all the mineral deposits of the world, even with respect to one mineral. It is, however, practicable through international co-operation to arrange for every country having a complete set of minerals from all the important mineralised districts of the world, along with a brief note on the geology of the deposits. Such an exchange of samples would be of great help in exploration.

55. Facilities for training of personnel:- Training facilities can be extended in two ways. Specialists in different branches of exploration can be sent to the under-developed countries for training personnel in those countries. Opportunities for training in the advanced countries can be provided to selected persons from the under-developed countries. Help in both the directions is presently being extended, but the scope of such help requires to be further increased.

56. Supply of equipment and instruments to under-developed countries:- Help is being received by the under-developed countries in the matter of supply of equipment and instruments, but it is still far from adequate. Assistance in the manufacture of equipment and instruments in the under-developed countries would represent a more fundamental and satisfactory solution for this problem, and should be extended in increasing measure wherever opportunities exist.



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SOBRE LA APLICACION DE LA CIENCIA Y LA TECNOLOGIA
EN BENEFICIO DE LAS REGIONES MENOS DESARROLLADAS**

Punto del programa : A.5.2.3

México

**FACTORES QUE LIMITAN
LA MECANIZACION DE MINAS
EN REGIONES MENOS DESARROLLADAS**

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**FACTORES QUE LIMITAN LA MECANIZACION DE MINAS EN REGIONES
MENOS DESARROLLADAS**

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A.- FACTORES GEOGRAFICOS.

1.- Los factores geográficos, Clima, Orografía, Hidrografía, no establecen por sí causa de limitación en el desarrollo de la mecanización, pero si, aunados a factores de diferente índole, privativos de las regiones de poco desarrollo tecnológico; aumentan los obstáculos para el logro de esos fines.

2.- Un factor geográfico determinante es la ubicación -- con respecto a los países productores de equipo, en virtud, -- primero de la menor oportunidad de los empresarios nacionales, de observar el uso de esos equipos, circunstancia que -- cuando existe, desarrolla en los mineros, por la enseñanza objetiva que la operación representa, el hábito de usar maquinaria.

3.- Otro factor es la distancia a los centros abastecedores de maquinaria y refacciones, por las inversiones fuertes que representan los almacenamientos de estos bienes, indispensables para asegurar la operación de las minas o plantas de tratamiento.

B.- FACTORES GEOLOGICOS.

B.1.- Tipos de depósitos.

4.- Depósitos de gran irregularidad presentan obstáculos a la aplicación de equipo mecanizado, ya que la explotación debe hacerse con un alto grado de selectividad. Esta -- condición es posible lograrse por medio de trabajo manual, -- que es mas accesible en países de economía poco desarrollada.

B.2.- Magnitud de los Depósitos.

- 5.- La magnitud del yacimiento por explotar es determinante de la inversión que debe hacerse en equipo para realizar la explotación costeable. En el caso de las regiones poco desarrolladas, este factor adquiere mayores proporciones, en atención a que como se ha expresado en el primer punto, se requiere que la inversión en equipo sea mucho mayor que la necesaria en los países manufactureros de la maquinaria; en donde el equipo en operación y las refacciones, se reducen, a una mínima parte.

B.3.- Leyes de los Minerales.

- 6.- Las Leyes de los minerales contenidos en un depósito, en relación con la magnitud del mismo, definen el programa de explotación, así como las inversiones que deban realizarse. Estas en los países de economía insuficientemente desarrollada, son superiores a las que para iguales condiciones se requieren en países productores de maquinaria y por lo tanto las leyes mínimas costeables, en función de las que deba recuperarse la inversión en equipo, deberán ser superiores a los del caso de los países productores de maquinaria.

C.- FACTORES HUMANOS

C.1.- Mano de Obra.

- 7.- Un factor de importancia primordial en la limitación del uso de equipo, es el bajo costo de la mano de obra en los países comprendidos en la clasificación de poco desarrollados.
- 8.- El contar con mano de obra muy barata, hace poco estimulante, a el empresario, realizar inversiones que deben ser recuperadas, a través de la amortización, con el consiguiente cargo a los costos.
- 9.- La mayor parte de las minas, propiedad de empresarios nacionales, operan a pequeña escala y han sido iniciados con muy escasos recursos de capital, en esta forma ha sido el

trabajo manual el empleado y aunque, el uso debido del equipo, ayuda a reducir costos; su aplicación se hace lentamente y a medida que los rendimientos de la mina van incrementando el capital.

C.2.- Dirección Técnica.

10.- Los empresarios, dada la reducida magnitud de operaciones y las dificultades que encuentran para incrementar sus capitales, tratan de ahorrar dinero no pagando servicios profesionales.

11.- La falta de asesoría técnica a través de la cual se planea la explotación sistemática y se difunden las nuevas técnicas de explotación y el uso de maquinaria es otro de los factores que retardan la mecanización.

D.- FACTORES ECONOMICOS.

D.1.- Inversiones.

12.- La falta de inversiones en la industria minera, o realizada de manera insuficiente, impiden la adquisición de equipo. Como se ha puntualizado en el párrafo B.3 del capítulo B, los rendimientos obtenidos en la explotación en pequeña escala y en la mayoría de los casos, en el límite de costeabilidad, impiden distraer los fondos para la compra de maquinaria.

D.2.- Disponibilidad de divisas.

13.- La mayor parte de los países poco desarrollados registran situación desfavorable en su balanza de pagos. Esto tiende a restringir las importaciones de equipo o a gravarlas fuertemente, con la finalidad de evitar la disminución en sus reservas de divisas.

D.3.- Fluctuación en las cotizaciones de los metales.

14.- Factor de inestabilidad económica en la fluctua—

ción en las cotizaciones de los metales que impide realizar in versiones con base en ingresos presupuestados a plazos concor dantes con las tasas de depreciación. En el caso de algunos minerales, las fluctuaciones en cotización van acompañadas de supresión total de la demanda, ejemplos Tungsteno, Antimonio.

D.4.- Política proteccionista de los países consumidores.

15.- Los sistemas de protección que los países consumido res de metales y minerales han establecido en beneficio de — sus mineros, aún en casos en que esos países registran fuertes déficits entre su producción y consumo, es otro factor de ineg tabilidad que impide la programación de mecanización de las — minas en los países productores de materias primas.

16.- Ejemplos recientes son el sistema de cuotas aplicado por los Estados Unidos a las importaciones de Plomo y Zino, — que ha hecho descender los precios de estos metales de manera continua.

17.- Otra causa reciente de baja en los precios de los — metales ha sido la venta de parte de los almacenamientos form ados por los Estados Unidos, con fines estratégicos, que ha provocado grave inquietud entre los productores, impulsando — los a vender sus metales a precios inferiores a los cotizados, en su ansia de dar salida a sus producciones antes de que se registren nuevas bajas.

18.- D.5.- Producciones cuativas.

Las grandes empresas en su mayor parte extranjeras — en los países poco desarrollados, han seguido la política de establecer las plantas de afinación de los metales en sus paf ses de origen. Esta afirmación es válida en varios países, — para el Plomo, Zino, Cobre, Tungsteno, Fluorita, Estaño y Alu minio.

19.- El hecho de que las plantas de afinación estén esta blicadas en los países de origen de las empresas, trae las si

guientes consecuencias lesivas a la economía de los países — productores.

- 20.- Se deben cubrir altos fletes hasta la planta de afinación, generalmente en moneda extranjera.
- 21.- Los gastos de afinación se pagan en moneda también-extranjera, comprendiendo jornales altos, correspondientes al desarrollo económico de esos países.
- 22.- En los procesos de afinación se obtienen subproductos (ácido sulfúrico, Cadmio, Selenio, Bismuto, etc.) que no son pagados a los productores y por los cuales el país no percibe impuestos.
- 23.- La falta de metales afinados, impide a los países — subdesarrollados el establecimiento de industrias manufactureras.
- 24.- Todas estas circunstancias, reducen los rendimientos por la explotación de las minas y contribuyen a la limitación de las posibilidades de inversión en equipos.



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UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item:A.3.1

United Nations

APPROACHES TO WATER RESOURCES DEVELOPMENT
IN DEVELOPING COUNTRIES

By The Department of Economic and Social Affairs,
United Nations,
New York

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)



UNITED NATIONS
CONFERENCE ON THE
PROLIFERATION OF NUCLEAR
WEAPONS

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.

3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

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APPROACHES TO WATER RESOURCES DEVELOPMENT

IN DEVELOPING COUNTRIES

by

The Department of Economic and Social Affairs

United Nations, New York

1. In view of the basic importance of water to life and to any economic development activity every developing country is, or should be, concerned with the development of water resources. The rapidly growing interest in this field is reflected in government development plans and also in requests for technical and financial assistance to the United Nations organizations concerned.^{1/} The present paper concentrates on a few salient points shown by United Nations experience to be particularly important, primarily as related to formulation and implementation of water development policies.

2. Particular attention deserves to be given to formulation of water policy and development decisions, and to the companion problems of organization to implement them, for several reasons, among them the facts that the key to success lies in this area and that a comprehensive approach is often lacking. Sound water policy is based on an adequate factual knowledge, which in the first instance requires the undertaking of surveys of current water uses and future needs and appraisals of water resources. In this process account should obviously be taken of new concepts for water resources development and new techniques. This paper briefly reviews the various aspects of a water policy. Before dealing with each of them, however, it is important to stress several basic characteristics, some of which distinguish water resources development from that of other natural resources and which influence the policy problems and their solutions.

Some basic characteristics

3. All countries have water resources. Many have too little water, some too much at least at certain times. The water needs and the urgency of water resources development differ with stage of development and type of area, such as illustrated by differences between humid tropical and arid areas. Hence the problems range from provision of drinking water at least, to coping with floods. In addition to the primary need for drinking water,

^{1/} Activities of the various United Nations organizations in this field are described in the first and second biennial reports of the United Nations Water Resources Development Centre, which is located at United Nations Headquarters and acts as the focal point for co-ordination and exchange of experience.

there are the problems of developing water supplies for industrial, agricultural and other uses, and of putting water resources to use for hydro-electric production, navigation, fishing, recreation and other purposes. Many of these needs have in the past been met through single-purpose development but are now approached to an increasing extent through multi-purpose schemes. The modern approach also considers alternative solutions, where feasible, and in this connexion is guided by comparative cost studies. In fact, the problems are often not so much purely technical as administrative, organizational and economic, notably when water is scarce and priority allocation to different uses has to be made.

4. There is usually no substitute for water, only techniques for economizing use such as by re-use and alternative processes or by metering and other price policy devices.

5. Water is an extremely bulky "commodity". It can be economically transported over only limited distances. It hardly enters foreign trade and is free from foreign exchange considerations, except as regards equipment for water resources development and utilization. Water has to be supplied from more or less local resources, where available, so that industrial and other potential users normally have to be located near the water resources, as illustrated since time immemorial by the concentration of populations in river valleys. In many aspects problems of water needs and supply thus have to be approached on an area and local basis even in relatively small countries; in some cases, however, the unit to consider is a whole hydrographic basin, which can indeed be large and also involve special problems as in the development of international river basins.

6. Except for some types of ground water, water resources are renewable, through replenishment provided by the balance between precipitation and evapotranspiration in the hydrologic cycle. The replenishment, and consequently the potential supply particularly in the case of surface water, vary with season and over the years in a not completely predictable fashion.

7. A large part, and in some countries the great bulk, of water use is non-consumptive, that is the water is not eliminated by its use from the total water supply of an area. Most of the water used for municipal and industrial purposes is non-consumptive water and remains available for re-use, although it may require reconditioning because of pollution, temperature and other quality changes before it can be used for subsequent purposes. Sometimes the water is not even changed in quality or little affected in this respect, as in the case of navigation, fishing and recreation. Hydro-power production leaves the water unchanged except for its altitude. Consumptive uses, on the other hand, eliminate water from the supply and therefore may have to be looked upon differently in policy formulation and planning. The most important application in this category is irrigation, in which water is used only once and mostly becomes either a part of the crop or, more importantly, is largely lost.

8. Water resources development and utilization must be planned years ahead in anticipation of population increase and economic growth. Considerable time is required for planning and construction, particularly in surface water development; hydrologic data, for example, usually have to be collected over

many years for the proper and safe design of large-scale structures. Moreover, foresight and early action are required to ensure adequate flexibility in access to water resources, which are often barred to potential users by antiquated water laws or traditional rights in the absence of water law. Delays only serve to strengthen vested interests of uses and of local water agencies possibly mushrooming in a haphazard fashion, as has happened in industrial countries, for lack of a comprehensive approach to water resources development.

Surveys of current water uses and future needs

9. Since water resources development aims at meeting needs, it is important first of all to have a reasonably clear picture of what those needs really are and may be expected to be. This side of the ledger is often neglected, partly because it is relatively difficult to assess present and especially future needs; this requires the skill to take account also of development planning, cost and value of water for different uses and problems of forecasting. Also, the "demand" side may be neglected for lack of a competent organization or authority to carry out comprehensive surveys in the face of pre-occupation with partial interests such as sanitation, irrigation or hydro-power production in functional ministries. Still such surveys are essential to policy formulation and also to guide the survey of water resources going ahead simultaneously. Stress must thus be laid on undertaking as early as possible at least a general assessment of the present and future water needs of each sub-region of the country.

10. Based on a division of the country into regions, normally corresponding to hydrographic basins, the comprehensive survey seeks to account for the water requirements in terms of those of human consumption, various branches of industry, mining, irrigation, stock-raising, power production, etc. The inventory may start with an investigation into present uses, which unfortunately in most cases are poorly documented with statistics. The picture then may be built up with information on population trends, industrial and other development plans and various methods of projection. The quantity requirements may be established with the aid of key figures on present and expected per capita use as regards human requirements, similar data for different types of industries, irrigation crops, processes, etc. Close attention must also be paid to the water quality requirements, which vary greatly between and within major functional sectors; in industry, for example, a high degree of purity is required for water entering food or pharmaceutical products while sea water is frequently used for cooling in thermal power and other plants. Similarly, careful consideration may have to be given to the effect the prospective use will have on subsequent availability and quality. Keeping

2/ The forecasting is complicated by the fact that a discovery of new water resources may create a corresponding actual demand, as in very arid areas or where lack of water is the factor limiting development.

3/ Key figures on water requirements per unit of product in selected industries, for example, are available in Water for Industrial Use, United Nations publication, Sales No.: 58.II.B.1.

in mind re-use of water and the problem of supply generally, it is of course essential to indicate the location of major users in the sub-region so that information is obtained for instance as to whether it is proposed to locate a "dirty" industry upstream from another requiring clean water and as to the relative location of major consumptive and non-consumptive users; for example by locating an irrigation project using up water upstream a major industry downstream may be left without adequate water supply while with the opposite location the industry may use the water first before it goes to irrigation.^{4/} The survey should also bring in information on current costs of water and the water costs which different current and prospective uses can stand.

11. This survey, when coupled with the simultaneous survey of water resources, will be basic to water policy considerations and probably a whole series of decisions. In water-short areas, for example, it will pinpoint mutually competitive needs at present and in later stages of the prospective development. The results may necessitate reconsideration of industrial and other development plans, changes of water laws and other decisions; if obtained sufficiently early, they will permit timely planning before acute problems arise.

Surveys of water resources

12. The surveying of water resources is a never-ending task. It is undertaken in stages ranging from broad preliminary reconnaissance to detailed investigations, feasibility studies and planning in preparation for actual development decisions. Geographical and topographical distribution and other features of water resources are related to demand areas; work is of course concentrated on useful water resources, in co-ordination with surveys of needs, so as to make the survey results helpful for policy and planning decisions.

13. The surveys should cover both surface-water and ground-water resources in a co-ordinated whole whether they are undertaken by one or several agencies. With respect to both types of resources there are now available many new techniques and tools as a result of advances in scientific hydrology, geophysics and other disciplines.^{5/} The surveys may be built up into an inventory or a more formal, perpetual cadastre registering not only the results of the initial survey but gradually also information on water use and other aspects such as water rights.

^{4/} In this connexion it should of course not be overlooked that e.g. new industries in themselves using relatively little water may bring with them significant urban development requiring large water supply.

^{5/} For comprehensive reviews, see for example respectively World Meteorological Organization, Techniques For Surveying Surface-Water Resources, Technical Note No.26, Geneva (1958), and United Nations Water Resources Development Centre, Large-Scale Ground-water Development, United Nations publication, Sales No.60.II.B.3. For further detail, reference is also made to papers under Agenda Items A.3.2 and A.3.3.

14. In locating and classifying water resources, data should be obtained as to both quantity (over time) and quality, including saline water which may be used directly for example in certain industries or converted at a cost to fresh water. In its more complete form, the survey will include adequate information on hydro-power potentials, possibilities for navigation and other development opportunities.^{6/} Stress will be laid on finding water supplies which have not been allocated.

15. As the resources surveys progress they will have to go into greater detail of physical data and especially give more consideration to economic factors required for appraisals, feasibility and planning studies. Beginning with rough estimates of costs of potential development they proceed to more exact information for promising resources, including breakdowns of costs for dams or wells, distribution systems and so forth. In this connexion it may be noted that the investment required in the development of the resource proper is only the beginning and may have to be accompanied by far larger investment for subsequent stages.^{7/} Early attention is also advisable with regard to the magnitude of foreign exchange costs in the prospective water resources development, for example for multi-purpose water structures, wells, pipes and so on. Sometimes there will be alternative ways, which should be looked out for, in meeting particular needs; they may differ in total cost or at least in composition as to foreign exchange requirements, labour and capital intensity and other factors of importance in the country's total development effort.

16. Already the reconnaissance survey will in all likelihood indicate many gaps in the knowledge of water resources, as has been the case in country surveys undertaken with United Nations assistance; several of these have since been followed with the establishment of hydrometeorological networks and similar projects, aided by the United Nations Special Fund, to help fill the gaps.

17. Country surveys of water resources, besides being essential to comprehensive water policy formulation, will have many beneficial effects. Their results will indicate solutions to present needs, be a useful guide to selection and location of industries and other activities, and in general create a better consciousness of water limitations and possibilities.^{8/} The resources surveys form an important first step towards development of water supply making possible new settlements, better health, increased agricultural production, new industries and other benefits for the developing economy.

^{6/} As regards hydro-power potentials it may be of interest to note that on the basis of inadequate exploration it is estimated that less than 10 per cent of the potential in Latin America is utilized and in Africa and Asia less than 5 per cent.

^{7/} In the overall experience of public water utilities in the United States, for example, pumping stations, distribution systems and filter plants - that is, stages after the development of the resource itself - account for over 80 per cent of the total investment.

^{8/} This consciousness may lead to avoidance of surprises such as are known to have happened in some cases where plans have been drawn in detail for particular industries - with water supply taken for granted - and then been upset upon discovery that adequate water was not available or cost too much

New techniques and concepts for water resources development

18. The evolution of new techniques in the development as well as in the exploration stages, has made approaches on a different scale possible and led, in a continuous process of inter-action, to revisions of the concepts underlying modern utilization and water management.

19. The advances on the technical side can be but briefly referred to here by way of a few examples. Surface-water development, for instance, has been profoundly affected by modern earth-moving equipment and possibilities opened by improved knowledge of soil mechanics for building earth dams, not to mention methods of blasting and moving rocks and use of steel and concrete for huge dams; other advances in this category include techniques for barrages, river diversion, lock construction, new turbines and pumps, long-distance power transmission and the use of hydraulic models. Ground-water development has been advanced not only through greater accuracy in locating and assessing ground-water resources but also by modern drilling to great depths, which are limited only by economic considerations; parallel with this may be noted advancing techniques and equipment for completing wells, efficient pumps such as submersible pumps and power drives to match them as well as techniques for underground storage and ground-water recharge. Note should also be taken of advances in water treatment and ways of improving water quality, including demineralization processes and possibilities for utilizing sea and brackish water.^{9/}

20. Integrated river basin development is among the concepts made possible by technical advances. The concept is, however, based on an integration also of economic, social, administrative and legal considerations, which cannot be entered into here.^{10/} It provides a framework for action involving the co-ordinated and harmonious development of the various works in relation to all the reasonable possibilities of the basin. Several steps will obviously have to be taken in the application of the concept, ranging from broad preliminary investigation to operation of new structures. Within this approach can then be accommodated both early planning on a big scale and also early implementation of small-scale projects, such as on tributaries, fitting into the bigger scheme but not needing to await the construction of main-stream dams.

21. The concept and approach will have to take into account additional problems and considerations when the river basin is international in scope. Regional and international co-operation then becomes clearly necessary for.

^{9/} The United Nations Department of Economic and Social Affairs currently is carrying out a survey of potential economic applications of demineralization of sea or brackish water in arid or semi-arid areas of under-developed countries experiencing fresh-water shortages. The report on this survey is scheduled for publication late in 1963.

^{10/} For a comprehensive study of this subject, see Integrated River Basin Development, United Nations publication, Sales No.58.II.B.3.

proper study and development of the resources, as illustrated by the Mekong River Project.^{11/} It is thus not surprising that international river basins are gaining increasing attention in the United Nations, which is in a unique position to assist in such cases involving several countries.

22. Ground-water development also is now increasingly approached through the application of modern concepts. It has come a long way from the traditional, sporadic production of ground water from hand-dug wells placed here and there, perhaps with the guidance of water diviners. Owing to advances in technology as well as increasing demand for water, development of ground-water resources now can be, and is, approached on a large scale spanning whole hydrogeological basins or countries. Drawing fully on relevant scientific disciplines, the approach is systematic in its entire range of stages from hydrogeological investigations and assessment through development surveys and planning to drilling of production wells, testing and maintenance. Again, it provides a framework of action which gives consideration also to organizational and other non-technological aspects and fits the various elements together whether they be geophysical surveys or the drilling of particular wells to meet pressing needs.^{12/}

Water policy problems

23. Water resources development is part of, and basic to, economic development. It ought to be guided by the evolution of water policy which clearly defines the aims of the State and, as a tool of economic development, is in harmony with broader goals and policies. That evolution of policy and planning decisions, in turn, are aided by the application of the approaches and considerations discussed above. The policy must be supported by a corresponding programme of action and organizational provisions to carry it out. Certain aspects will require to be expressed in water legislation.

24. The problems, contents and emphases of water policy will of course vary with local conditions and with the factual findings of the specific case. Without reference to particular place and time, they can be taken up here only by way of a few illustrations of issues and elements.

25. One set of basic problems concerns water rights, which must in most cases be clarified through water legislation along with a series of related questions. The doctrines applied in this respect range from absolute private ownership permitting unlimited use to public ownership with various systems for regulating use. Legislation on this point, as on others, should be concise and enforceable but also flexible so that effective use can be made of the resources.

^{11/} For a description of the project, see for example Annex II of The United Nations Development Decade, United Nations publication, Sales No. 62.II.B.2.

^{12/} For further details, see Large-scale Ground-water Development, United Nations publication, Sales No. 60.II.B.3.

26. An important criterion in the priority allocation of water use is that of economic efficiency. This criterion, which may be resisted by vested interests, takes into account the relative contribution, per unit of water, of different uses to national income, that is to say the product value produced through the use of a given quantity of water in different potential applications, such as various industries and types of irrigation crops. Wide variations will usually be found in this respect, particularly as between industry and agriculture. If water were a normal commodity, such differences would be reflected in the market; the application of the economic productivity criterion in water allocation, in water-short areas, is in essence a substitute for the price mechanism that balances supply and demand in normal commodity markets. It can provide an impartial and effective yardstick but may need to be supplemented with special considerations, such as with regard to drinking water requirements and traditional rights in the light of long-term goals.

27. To some extent, water price policy itself may be used as an allocation tool; when coupled with metering, it can become an effective device for conservation by relating water charges to quantities used. In most cases, however, water pricing is not treated primarily from the allocation point of view but rather in relation to the problem of financing and reimbursing public investments in water resources and supply development;^{13/} the latter problem of course raises a whole series of policy questions. They are not however unique to water resources development, which must be reviewed with regard to (foreign and domestic) capital, labour and other requirements like any other developments and in conjunction with them, as is done in overall economic development plans.

28. A related problem is that of appraising water resources projects and making planning decisions. In this connexion it is worth stressing the growing role of systematic economic studies as a tool and the importance of familiarity with their techniques of comparative cost analysis, evaluation of benefits and application of investment criteria.

29. Another necessary preoccupation of policy concerns conservation of water. Conservation measures range from reduction of large losses through evaporation, transpiration and run-off, to attacks on the - more controllable - losses due to wasteful uses of water, including overpumping of ground-water resources. The techniques of conservation are numerous and in fact beyond the scope of this paper except for stressing that their selection must be governed by economic considerations rather than by the aim of conservation for its own sake. The policy considerations should take into account

^{13/} Water prices are in fact often subsidized; this practice may be of doubtful value in the long run, particularly since it is likely to result in mounting difficulties on account of increasing costs both for replacement works and especially for developing additional water resources and supplies.

conservation of water quality as well as quantity. In this context particular attention may be paid to re-use and reconditioning of water and to the related question of control of water pollution, which is becoming a serious problem in many places.

30. Whatever the specific water policy problems, it is necessary that the basic policy reflects long-term goals and that provision is made for sufficient flexibility permitting adaptation to changing conditions. After a comprehensive approach and policy have been worked out, there will be a need for periodic re-examinations of policy and for continuous adjustments through the organizations set up to implement water policy and water resources development.

Organizations and programme of action

31. The form and tasks of organizations in the water field reflect water policy, or lack of policy. Where a comprehensive approach is applied, there will normally be a correspondingly clear organization, with responsibilities set out in water legislation or other form, to ensure that water resources are properly explored, developed and conserved and that they are allocated fairly to the various uses.

32. The role of public water authorities varies from country to country, and so does the type of organization. The organization is related not only to the scope and contents of water policy and development programmes but also to the historically evolved structure of the central government and local conditions. The functions may be centered in a government ministry or corporation, but more commonly they are divided, partly for historical reasons, among various government ministries, departments and organizations.

33. Sometimes this division is clearly established, at least on paper, by function, such as surface-water surveys being handled by a hydrometeorological organization, ground-water exploration by a geological survey department, construction by a public works ministry, irrigation development by a ministry of agriculture, hydro-power development by another department, river navigation development by a ministry of transport, health aspects by a ministry of public health, and so forth. In practice, this division amounts to fragmentation of efforts and may result, as has happened in some countries, in the organizations working at cross-purposes without regard to other related activities and broader interests.

34. The comprehensive approach considered in this paper serves to bring order into this situation. It is emphasized particularly in relation to the less developed countries, where the organizational set-up usually is still relatively fluid and where an integrated approach to water resources development may be not only easier but also more important. The integration does not necessarily require centralisation in a single department or autonomous government organization, though such an establishment may be able to carry out the most effective water resources development. But at least the efforts and programmes should be effectively co-ordinated through inter-departmental co-operation, which may be secured by means of a body at the

ministerial or other higher level or, better still, by a national water resources board. The latter type of top organization should be in an excellent position to ensure a comprehensive approach taking fully into account the various factors and interests involved and to develop water policies and programmes best serving the developing country. It must of course have adequate authority and be able to rely on a sufficiently equipped subordinate organization to implement the policies and programmes.

35. The size and scope of the staff in the water organization will of course vary from situation to situation and depend, for example, on the extent to which work is done on outside contract. Here it is only necessary to emphasize that sufficiently competent staff be acquired or developed to do the job at hand and that adequate attention be given to the training of staff to meet these needs in the developing countries. The staff must also be provided with adequate tools and equipment to be able to do a good job.

36. The effectiveness of water resources development programmes is only as good as the organization carrying them out. Governments are keenly aware of this; many of them have turned to the United Nations and other sources to meet their pressing needs, and more are becoming aware of the possibilities for assistance.

37. Hence it is not surprising that water resources development has been growing in importance in the international assistance field. It has come to include, for example, United Nations technical assistance in reviewing water policy, undertaking preliminary country surveys of water resources and needs, setting up organizations and implementing various water projects; numerous water resources surveys in the "pre-investment" category assisted by the United Nations Special Fund; and loans from the International Bank for Reconstruction and Development and its affiliate the International Development Association to finance major water development projects. In these and other related activities the various United Nations organizations concerned, as noted in the introduction, co-operate and pool their experience through the United Nations Water Resources Development Centre.



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ORIGINAL : ESPAÑOL

**CONFERENCIA DE LAS NACIONES UNIDAS
SOBRE LA APLICACION DE LA CIENCIA Y LA TECNOLOGIA
EN BENEFICIO DE LAS REGIONES MENOS DESARROLLADAS**

Punto del programa : A.3

Chile

**METODOS HIDROLOGICOS UTILIZADOS
PARA EL DESARROLLO HIDROELECTRICO DE CHILE**

Por Eduardo BASSO S.,
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Las monografías presentadas en la Conferencia de las Naciones Unidas sobre la Aplicación de la Ciencia y la Tecnología en Beneficio de las Regiones Menos Desarrolladas constituyen documentos de trabajo de dicha Conferencia. Se publican tal como han sido presentadas por los colaboradores y los puntos de vista expresados en ellas corresponden a los colaboradores. (Véanse notas al dorso.)

NOTAS

1. Las monografías seleccionadas para las Sesiones Generales serán distribuidas en la Conferencia en los siguientes idiomas oficiales de las Naciones Unidas: español, francés, inglés y ruso.

2. Las monografías seleccionadas para las Sesiones Especiales serán distribuidas en la Conferencia únicamente en uno de los idiomas oficiales antes indicados.

3. Los resúmenes de las monografías presentadas por los colaboradores serán distribuidos en la Conferencia en los siguientes idiomas oficiales de las Naciones Unidas: español, francés, inglés y ruso.

4. No se procederá a la distribución general de las monografías y resúmenes con antelación a la Conferencia. Únicamente serán publicadas en cantidades limitadas con antelación a la Conferencia para uso exclusivo de las delegaciones de los gobiernos participantes y de otros participantes autorizados. La publicación con posterioridad a la Conferencia y la distribución general de las actas y debates de la Conferencia seguirán las prácticas de las Naciones Unidas establecidas por la Junta de Publicaciones de las Naciones Unidas.

MÉTODOS HIDROLÓGICOS UTILIZADOS PARA EL DESARROLLO
HIDROELECTRICO DE CHILE

por Eduardo Basso S.

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1.- Generalidades

Para el diseño de las centrales hidroeléctricas que constituyen el núcleo de la labor que el Gobierno de Chile ha encomendado a la Empresa Nacional de Electricidad, S.A., (ENDESA), es indispensable contar con la adecuada información hidrológica. La política normal en países en desarrollo tiende hacia un descuido en la recopilación de la información básica, aparentemente improductiva en sus comienzos.

A pesar de que en el momento de creación de ENDESA existía un servicio hidrológico relativamente aceptable, el criterio de los fundadores de esta Empresa fue visionario ya que se dió una extraordinaria importancia a la investigación de los recursos hidráulicos, la que sin lugar a dudas ha dado los frutos que de ella se esperaba.

El crecimiento de la Empresa hizo ver que la necesidad de la Hidrología no disminuía con la terminación de las primeras obras. Al revés, la operación eficiente de las centrales requirió mayor información, y la interconexión de las plantas obligó a una mejor predicción de los caudales de escurrimiento.

2.- Organización del Servicio Hidrológico de ENDESA

La hidrología de ENDESA ha sido encomendada a la División Hidrología, cuya ubicación dentro de la Empresa se indica esquemáticamente en la Fig. I.

Internamente la División consta de dos Sub-divisiones: Hidrometría y Estudios Hidrológicos, las que contaban con el siguiente personal, al 1° de Julio de 1962:

	<u>Jefatura</u>	<u>Sub-División Est. Hidrológicos</u>	<u>Sub-División Hidrometría</u>
Ingenieros	1	7	-
Técnicos	-	11	19
Personal Administrativo	2	-	2
Personal Auxiliar			
Permanente	-	-	5
Obreros (*)	-	-	50
Total	3	18	76

(*) Término medio para el primer semestre de 1962.

La Sub-División Hidrometría está encargada fundamentalmente de:

- a) Construir las instalaciones para medidas meteorológicas e hidrométricas.
- b) Hacer las observaciones, ya sea directamente o por medio de observadores dependientes de ellos.
- c) Mantener las instalaciones hidrométricas y meteorológicas en buen estado de funcionamiento.
- d) Hacer las computaciones preliminares de las observaciones.

A la Sub-División Estudios Hidrológicos se le ha encomendado:

- a) Elaborar los datos obtenidos en terreno.
- b) Proyectar las instalaciones hidrométricas y meteorológicas y supervigilar su construcción.
- c) Efectuar los estudios especiales que le sean solicitados, y
- d) Planificar los trabajos de Hidrología.

En la Fig. II se ha representado esquemáticamente la organización de la División Hidrología.

Desde un punto de vista geográfico la oficina central se encuentra ubicada en Santiago. Se están organizando tres centros regionales, en Santiago, Chillán y Osorno, cada uno de los cuales atendería a las oficinas de los hidromensores. Los territorios asignados a cada uno de ellos, se han dibujado en la Fig. III junto con las estaciones hidrométricas existentes y en proyecto.

En el futuro se proyecta dar más importancia a estos centros regionales junto con aumentar el personal destinado a mediciones, lo que se espera conseguir liberando a la Sub-División Estudios Hidrológicos de los cálculos rutinarios mediante el empleo de computadores electrónicos.

3.- Métodos utilizados en el período inicial

En el período inicial se contaba únicamente con escasos datos hidrológicos generalmente en zona de escaso interés hidroeléctrico, ya que la mayor parte de estos registros provenían de la Dirección de Riego del Ministerio de Obras Públicas. Esto obligó a utilizar una serie de métodos, parte de los cuales son originales que permiten suplir las deficiencias de los datos directos. Como este problema se presentará sin lugar a dudas en numerosos países que en estos momentos están en condiciones de iniciar su desarrollo hidroeléctrico, parece interesante dar a conocer dentro de las limitaciones al presente trabajo las ideas generales en que estos sistemas se basaron.

El primer problema radica en el control de los datos recopilados en el pasado y de los cuales no se conoce su precisión. Esto evidentemente se aplica no solo a los datos hidrométricos sino también a los datos meteorológicos.

Para precisar las ideas nos permitiremos explicar el sistema empleado para determinar una estadística de caudales. En primer lugar debe contarse con una estadística de niveles los que pueden ser productos de observaciones directas en un limnómetro o registro de un limnógrafo. Paralelamente debe hacerse medidas del caudal por algunos de los métodos usuales.

En Chile prácticamente solo se han empleado los aforos como molinete a los que recientemente se ha agregado el uso de aforos químicos. Con estos datos es posible dibujar una curva de descarga la que permitirá la traducción de los niveles en caudales. De ahí en adelante el trabajo es puramente estadístico. Normalmente las medidas de niveles son confiables y la única precaución de importancia que debió tomarse al revisar las estadísticas antiguas fué la de comprobar la invariabilidad de la cota del limnómetro.

Una de las fuentes más importantes de errores radica en la defectuosa ejecución de los aforos. Sin embargo, es prácticamente imposible corregir esta deficiencia y por lo tanto será necesario aceptarlos previo recálculo de acuerdo a una norma uniforme. Las fallas más importantes radican sin embargo en la determinación de la curva de descarga ya que esta curva cambia con los embanques y socavaciones que con mucha frecuencia ocurre en las frecuencias de control. Esto ha hecho que normalmente una sección de control cuente con numerosas curvas de descarga las que generalmente solo cumplen la condición de ajustar bien a los aforos considerados en el cálculo. Sin embargo, el empleo de ciertas premisas elementales permite convertir esta familia de curvas desordenadas en un conjunto armónico.

Las consideraciones que se han tomado en cuenta para el trazado de las curvas de descarga:

- a) Todas las curvas deben tener la misma forma.
- b) Para gastos muy grandes los efectos de socavación y embanque son despreciables y por lo tanto las curvas deben ser tangente en su parte superior.
- c) El caudal resultante de los cálculos hechos con estas curvas debe ser consecuente con los factores meteorológicos de la hoyá.

Para esto último debe procederse por tanteo: se calcula en primer lugar la estadística con una curva y luego se compara los volúmenes de escurrimiento resultantes con una precipitación característica de la hoyá. Esta comparación se hace utilizando el sistema de curvas místicas (suma de volúmenes - suma de precipitaciones). Si la estimación fué correcta los puntos se alinearán en una recta (Fig. IV) sino será necesario tantear con otras curvas de descarga hasta que esto se logre.

En la Fig. V se indica la forma en que se han representado esta familia de curvas de descarga.

La determinación de la precipitación característica representa en sí misma un problema de alguna complejidad, el cual no se tratará en este trabajo. Basta decir que para ello también se aborda aplicando el sistema de las curvas místicas, esta vez entre las sumas de las precipitaciones de dos estaciones de medida.

Una vez encontrada una estadística base aceptable es necesario determinar la estadística en el punto donde se ubique la bocatoma de la central hidroeléctrica. La omisión de controles en ese punto no puede aceptarse, pero en ciertos casos, razones de urgencia obligan a iniciar el diseño cuando solo se cuenta con pocos años de estadística. En este caso será necesario extender la estadística corta con el auxilio de la estadística base, corregida de acuerdo con el método ya expuesto.

El método a seguir sería esquemáticamente el siguiente:

- a) Corregir la estadística corta en la misma forma ya explicada.
- b) Hacer correlaciones, mes a mes, entre los gastos de la sección por extender (Q)

y los gastos de la base (Q_b). Se obtienen así curvas del tipo

$$Q = f(Q_b)$$

En general se prefieren las rectas de ecuación

$$Q = A Q_b + B \quad \dots (1) \text{ como se indica en la Fig. VI.}$$

- c) Los coeficientes A de la ecuación (1) deben tener una variación gradual. Si eso no ocurre se corrigen los coeficientes mediante el uso del gráfico representado en la Fig. VII.
- d) Los datos resultantes deben dar puntos alineados en la representación másica como se ha explicado anteriormente. Si no, deben revisarse las ecuaciones (1).
- e) Lo anterior garantiza la precisión del gasto medio anual. Para asegurar que los gastos medios mensuales dan valores satisfactorios, se dibujan curvas de variación estacional del gasto, las que deben tener variaciones lógicas. Una curva de este tipo se dibuja en la Fig. VII.

En algunos casos, ni siquiera se cuenta con estadísticas base. Para estos casos se han desarrollado métodos que pueden dar datos aceptables para datos de ante-proyecto, pero en ningún caso se pueden utilizar en diseños definitivos.

Dos métodos se han empleado de preferencia:

- a) Relación de superficies. Si se conoce el caudal (Q_b) de una hoya de características similares a la en estudio, su caudal quedaría dado por:

$$Q = \frac{A}{A_b} Q_b \quad \dots (2)$$

siendo A el área de la hoya en estudio y A_b el área de la hoya base.

- b) Rendimiento equivalente. Si además se conocen las precipitaciones P y P_b de ambas hoyas puede mejorarse el cálculo, utilizando

$$Q = \frac{A}{A_b} \frac{P}{P_b} Q_b \quad \dots (3)$$

Debe insistirse nuevamente en el carácter muy aproximado de estos métodos.

4.- Planeamiento de la red futura (2)

La red fluviométrica chilena contaba con 349 estaciones al 30 de Julio de 1961, esto corresponde a 0,50 estaciones por 1.000 km², esta densidad se indica en la Fig. VIII. Puede notarse que la densidad de estaciones en Chile corresponde a un standard aceptable. Debido a la gran diversidad geográfica del país a pesar de que algunas zonas están controladas adecuadamente en otras hay una carencia casi absoluta de estaciones. Esto es el caso de las dos provincias australes que son justamente las que contienen el mayor potencial hidroeléctrico.

- (2) Stream Gauging Network in the United States
Discussion by Eduardo Basso, Journal of Hydraulics
Division A. S. C. E., November 1961.

En vista de esta deficiencia, el Gobierno de Chile ha obtenido asistencia técnica y económica del Fondo Especial de las Naciones Unidas para y proyecto de expansión de la red de estaciones hidrométricas y meteorológicas.

Con esta expansión la red fluviométrica tendrá un minimum de 484 estaciones

(0.65 estaciones por 1.000 km²) al cabo de 4½ años. El Gobierno contribuirá con US\$ 1.220.000 al proyecto y el Fondo Especial con US\$ 612.500 en su mayor parte en equipos de importación.

El trabajo será ejecutado por tres oficinas: Dirección de Riego del Ministerio de Obras Públicas, Empresa Nacional de Electricidad S.A. ENDESA y Oficina Meteorológica de Chile.

En la Fig. III se indica la ubicación de las estaciones existentes y de las probables a instalar. Las áreas de concentración de estaciones corresponden a la zona de gran utilización de energía hidroeléctrica o las zonas en que existe un regadío intensivo.

El criterio principal utilizado para ubicar las nuevas estaciones ha considerado en especial el control de los principales ríos aguas arriba de las bocatomas de los canales de regadío y aguas abajo de las uniones de los mayores afluentes. Además algunas estaciones se ubicarán en las partes bajas de los ríos con el objeto de medir las aguas que pasan al mar. La densidad variable de la red propuesta corresponde aproximadamente a la densidad de la población. La completa ausencia de precipitación y escurrimiento en el desierto del norte hacen necesarios los controles en aquellos cursos que contienen agua en forma permanente u ocasional.

5.- Método para la estimación de crecidas

En el diseño de las obras de evacuación, bocatomas, embalses, etc. es necesario contar con la mejor estimación de la crecida que sea posible. A este respecto ENDESA ha estudiado la aplicación de varios métodos, de lo que se da cuenta esquemáticamente a continuación:

a) Métodos probabilísticos. Los caudales peak de cada año se llevan a un gráfico en función de la probabilidad. A estos valores se ajusta una función de tipo probabilístico. La más utilizada en Chile es la distribución normal - logarítmica. A fin de facilitar los cálculos se utiliza un rayado especial que permite ajustar una recta, como se indica en la Fig. IX. Luego se lee el caudal correspondiente a la probabilidad de la crecida extrapolando este ajuste. Este método da resultados satisfactorios cuando las estadísticas son largas y confiables, pero conduce a resultados erróneos en caso contrario.

b) Hidrograma unitario. Este método es usual y se trata en la literatura hidrológica, y por lo tanto no se analizará en este trabajo. Requiere una inscripción continua del gasto, y por lo menos un pluviógrafo, condiciones que en muchos casos no se cumplen. Si estos datos no están disponibles se puede utilizar el hidrograma unitario sintético. En este método el hidrograma unitario (curva caudal - tiempo, para una precipitación unitaria) es función de las características de la hoya y de dos constantes que se determinan para la zona en estudios. Estos coeficientes se han determinado para la zona central de Chile (3).

(3) Aplicación del Método de H. U. sintético a la zona central de Chile.
Informe N° 23, División Hidrología, ENDESA.

c) Predicción del rendimiento de una hoya. Si H es la precipitación caída sobre una zona de superficie A, el volumen caído es:

$$V = H A \quad \dots (4)$$

de esto escurrirá un N%; o sea:

$$V_e = N H A$$

Si se acepta una forma de distribución $N = f(t)$, el gasto máximo será:

$$Q = N H A f(t) \dots (5)$$

siendo t el tiempo transcurrido entre la iniciación de la lluvia y la producción del canal peak.

El valor y la forma de la función $f(t)$ deben determinarse experimentalmente. Para ello se está realizando una experiencia en terreno de la hoya afluente al lago Lliu-Lliu, en las cercanías de Santiago. En la actualidad se utilizan los datos dados por la experiencia extranjera.

- d) Envolvente de crecidas. Con este método se llevan en un gráfico los gastos peak unitarios en función de la superficie de la hoya, y se dibuja una envolvente por los gastos mayores. En Chile se han encontrado dos envolventes:

(i) Crecidas de lluvia

(ii) Crecidas de deshielo

En la Fig. X se presenta como ejemplo la envolvente de crecidas de lluvia.

El criterio preferido para la determinación de crecidas de diseño ha sido utilizar el máximo de métodos disponibles y decidir a la vista de todos ellos.

6.- Previsión de los caudales.

Ha sido necesario abordar dos tipos de previsiones de caudales:

- a) Previsiones de escurrimiento a largo plazo.
- b) Previsiones de crecidas.

- a) Previsiones de escurrimiento a largo plazo. En este caso es posible predecir los volúmenes de deshielo en función de los contenidos de agua en la nieve de las montañas de la cordillera de Los Andes. El método de muestreo de nieve es el usual en Estados Unidos y expuestos en numerosos textos.

Las correlaciones nivo-fluviales son bastantes buenas como puede verse en la Fig. XI, permitiendo deducir el volumen total del deshielo entre Octubre y Abril. El caudal peak (Noviembre o Diciembre) se determina con una correlación análoga. Los gastos de recesión se determinan en función de este caudal peak y los gastos anteriores al deshielo se calculan de modo que se complete un volumen total predecido.

Se llega así a errores variables según la zona del país, cuyo promedio es del orden del 5% para la predicción del volumen y del gasto peak y de un 10% a 15% para la predicción de los gastos de los demás meses.

- b) Previsiones de crecidas. Este problema es de especial interés en la construcción de obras en la temporada lluviosa y en la operación de embalses. El método empleado es el "flood routing", con transmisión automática de los datos de niveles y precipitaciones con equipos radiotransmisores. La primera de las instalaciones de este tipo está funcionando para ser

utilizada en la predicción de las crecidas en la Central Rapel, bajo construcción. En esta central el río se desvía por un túnel que periódicamente no tendrá capacidad suficiente, inundando las obras, las que deberán ser evacuadas oportunamente para evitar daños y desgracias.

7.- Otras mediciones y estudios

La naturaleza de este artículo impide explayarse con más detalle en relación a numerosas otras actividades del organismo en estudio. De estas se hará solo una somera reseña.

a) Meteorología. Se controlan estaciones meteorológicas con el siguiente detalle:

Estaciones climatológicas	23
Fluviógrafos	14
Pluviómetros	68
Estaciones evaporimétricas	28
Estaciones para fines especiales	5

Esta labor es solo complementaria a la desarrollada por el Servicio Meteorológico Chileno que es insignificante en las zonas de interés hidrológico.

b) Hidrometeorología. En combinación con el Fondo Especial de las Naciones Unidas se está estudiando la relación entre la evaporación de un embalse y la evaporación medida con evaporímetros de varios tipos o la determinada con fórmulas.

Además se están estudiando los efectos reductores de capas monomoleculares de hexadecanol en embalses. Esta investigación se iniciará en el verano 1962 - 1963.

c) Transporte sólido. Para el diseño de sus centrales, ENDESA necesita una estimación de la sedimentación en el embalse que se formará con la construcción de la represa de la mencionada obra, y además se requiere una estimación del daño que el sedimento producirá a las turbinas y otras obras hidráulicas.

La División Hidrología de esa Empresa ha sido la encargada de la obtención de los datos y de su posterior elaboración e interpretación. En este tema se ha hecho progresos de alguna importancia, pero su relación se apartaría de la índole general de este trabajo.

8.- Conclusiones

El esquema expuesto da una idea somera de la importancia que tiene la hidrología para el desarrollo hidroeléctrico de un país en expansión. Lo dicho es igualmente aplicable a todos los demás proyectos de aprovechamiento hidráulico, casos en los que generalmente estos aspectos son descuidados. No es necesario insistir en lo perjudicial que esta política puede resultar (tranques que no se llenan o se infiltran totalmente; vetederos insuficientes, etc.) y siempre el dinero invertido en estudios e investigaciones hidrológicas es devuelto con creces.

Es también altamente satisfactorio constatar que toda esta labor ha podido realizarse con personal totalmente chileno, el que ha contado con facilidades para perfeccionarse en el extranjero y para dar y recibir asistencia técnica.

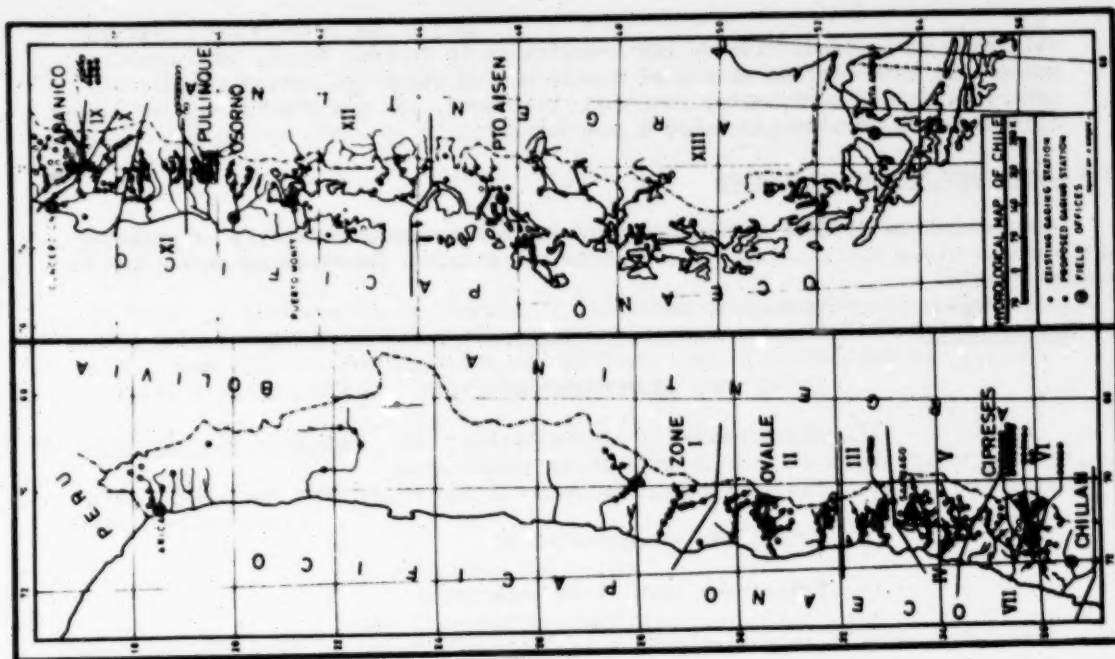
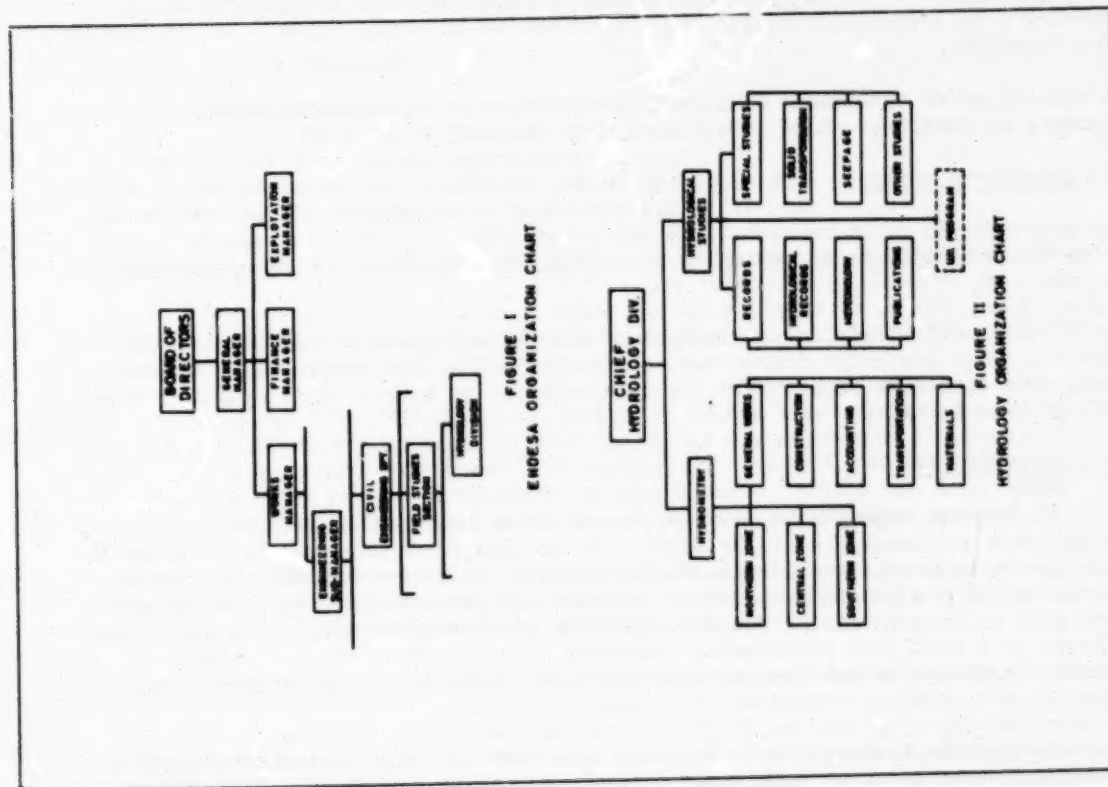


FIGURE III LOCATION OF HYDROLOGICAL STATIONS AND OFFICES



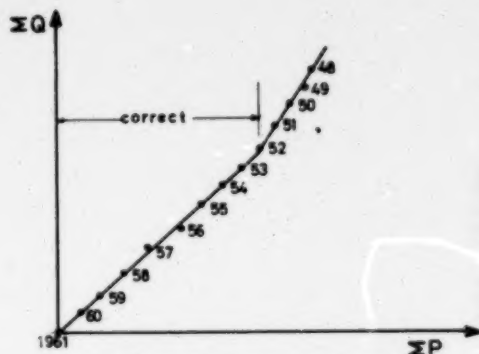


FIGURE IV MASS CURVE

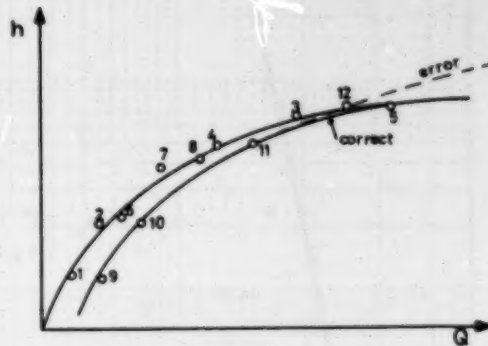


FIGURE V RATING CURVES

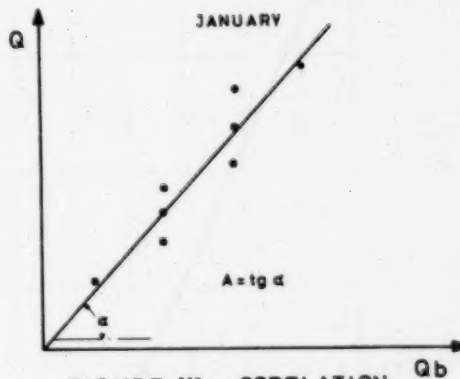


FIGURE VI CORRELATION BETWEEN FLOWS OF TWO RIVERS

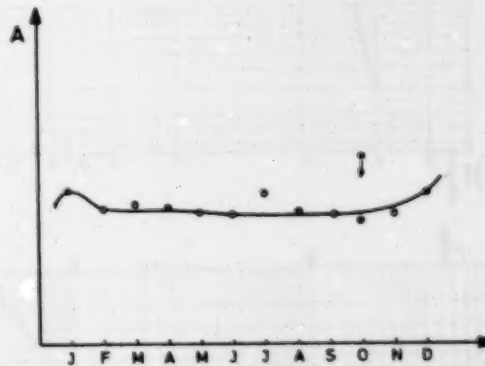


FIGURE VII CHECK ON VALUES OF A

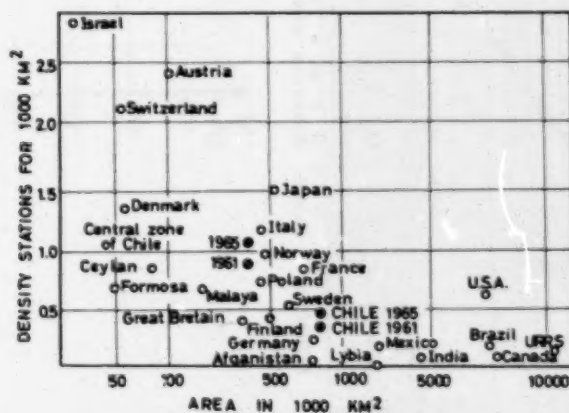
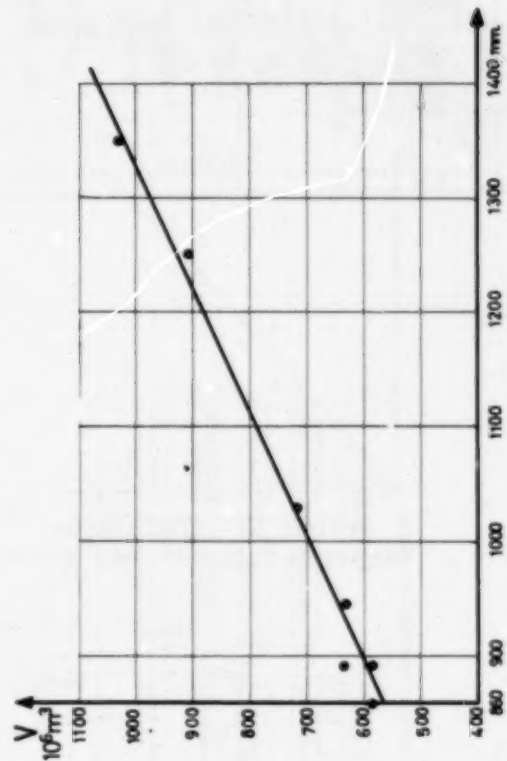
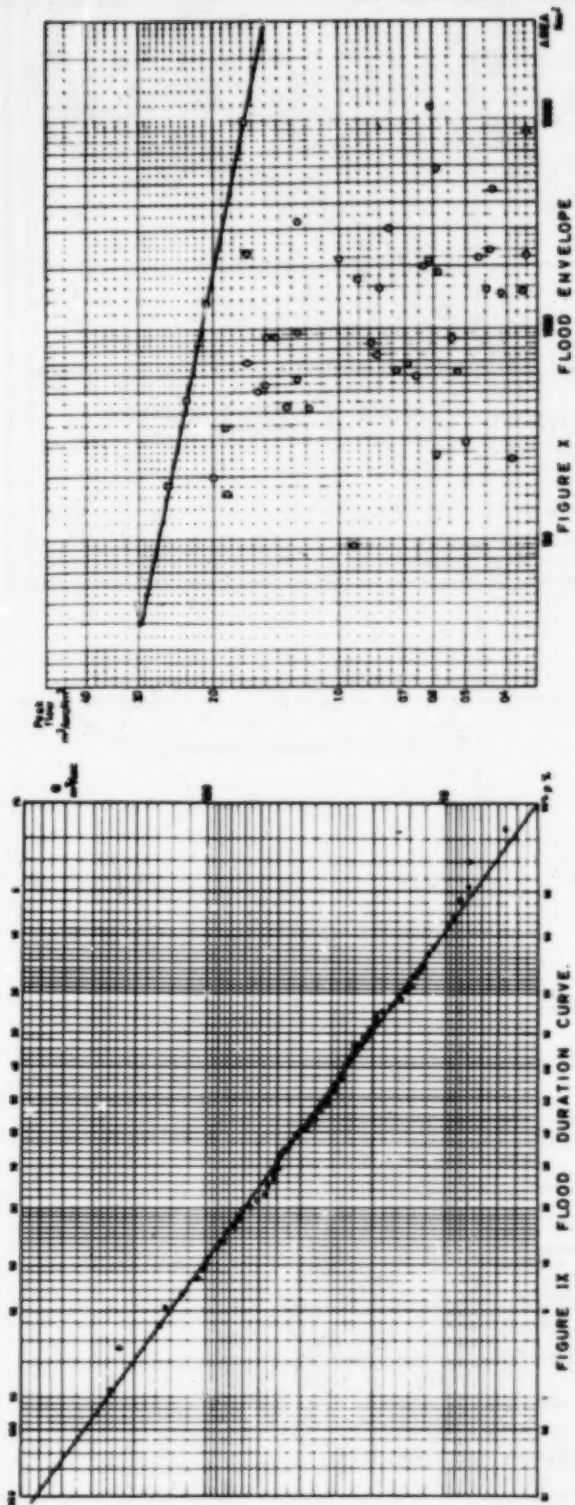


FIGURE VIII
COMPARED DENSITY OF GAGING STATIONS FLOW
NETS IN SEVERAL COUNTRIES





E/CONF.39/A/215

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ORIGINAL : ESPAÑOL

CONFERENCIA DE LAS NACIONES UNIDAS
SOBRE LA APLICACION DE LA CIENCIA Y LA TECNOLOGIA
EN BENEFICIO DE LAS REGIONES MENOS DESARROLLADAS

Punto del programa : A.4.2.3

México

ADELANTOS RECIENTES EN LA TECNOLOGIA DEL PETROLEO :
INCLUIDAS LAS INSTALACIONES PEQUEÑAS
PARA SATISFACER LAS NECESIDADES LOCALES
DE COMBUSTIBLES REFINADOS

Por Silvestre GUERRERO CASTILLO,
Ing.,
Petróleos Mexicanos

Las monografías presentadas en la Conferencia de las Naciones Unidas sobre la Aplicación de la Ciencia y la Tecnología en Beneficio de las Regiones Menos Desarrolladas constituyen documentos de trabajo de dicha Conferencia. Se publican tal como han sido presentadas por los colaboradores y los puntos de vista expresados en ellas corresponden a los colaboradores. (Véanse notas al dorso.)



NOTAS

1. Las monografías seleccionadas para las Sesiones Generales serán distribuidas en la Conferencia en los siguientes idiomas oficiales de las Naciones Unidas: español, francés, inglés y ruso.

2. Las monografías seleccionadas para las Sesiones Especiales serán distribuidas en la Conferencia únicamente en uno de los idiomas oficiales antes indicados.

3. Los resúmenes de las monografías presentadas por los colaboradores serán distribuidos en la Conferencia en los siguientes idiomas oficiales de las Naciones Unidas: español, francés, inglés y ruso.

4. No se procederá a la distribución general de las monografías y resúmenes con antelación a la Conferencia. Únicamente serán publicadas en cantidades limitadas con antelación a la Conferencia para uso exclusivo de las delegaciones de los gobiernos participantes y de otros participantes autorizados. La publicación con posterioridad a la Conferencia y la distribución general de las actas y debates de la Conferencia seguirán las prácticas de las Naciones Unidas establecidas por la Junta de Publicaciones de las Naciones Unidas.

ADELANTOS RECIENTES EN LA TECNOLOGIA DEL PETROLEO
INCLUIDAS LAS INSTALACIONES PEQUEÑAS PARA SATISFACER
LAS NECESIDADES LOCALES DE COMBUSTIBLES REFINADOS

por el Ing. Silvestre Guerrero Castillo
PETROLEOS MEXICANOS

1. En la industrialización realizada por Petróleos Mexicanos en México, se han aprovechado los adelantos tecnológicos más avanzados en la rama del petróleo para satisfacer de una manera más económica la demanda en el país de productos combustibles refinados, obtener una explotación racional de los campos productores y conservar al máximo las reservas.

2. El petróleo crudo, dada su naturaleza, es de muy variadas características, por lo que para procesarlo y obtener productos dentro de ciertas especificaciones establecidas se usan diversos métodos que permiten que la planta que se diseña, sea la adecuada para manejar lo más eficientemente un tipo de petróleo crudo, o una mezcla de varios.

3. Del gas natural también es posible recuperar productos líquidos que se usan en gasolinas e hidrocarburos puros como butano, propano y etano, o mezclas de los mismos.

4. Entre los principales procesos que han sido usados en México que pueden considerarse como adelantos recientes se encuentran los siguientes:

- a) Sistemas de plantas de absorción para recuperación de líquidos del gas húmedo
 - b) Obtención de materias primas petroquímicas de sistemas de refinación.
 - c) Plantas derivadas de la petroquímica.
5. Sistema de plantas de absorción para recuperación de líquidos del gas húmedo.

6. Durante la producción de un pozo, el petróleo fluye acompañado de una cantidad de gas que puede variar desde 300 pies cúbicos por barril, hasta 10.000 pies cúbicos por barril. A esta relación se le llama relación de gas a aceite. Si este gas se descarga a la atmósfera después de haber sido separado del petróleo, está siendo desperdiciada una gran cantidad de energía. En condiciones óptimas de operación de un pozo, la energía del gas debe conservarse para mantener el flujo del pozo y la relación de gas a aceite debe mantenerse baja para que el escape del gas sea el mínimo y se obtenga la máxima presión de flujo.

7. Tanto el gas natural que se obtiene de pozos productores de petróleo, como de pozos de gas, contienen hidrocarburos en forma de vapores e hidrocarburos puros, como butano, propano, etano o mezclas de ellos. El gas natural puede clasificarse como gas húmedo o gas seco.

8. Para recuperar estos productos, el gas natural se puede procesar de varias maneras. La forma convencional consiste en dos operaciones, la recuperación de los líquidos y la purificación de los mismos.

9. La recuperación de los líquidos, o sea la gasolina cruda, puede obtenerse de las siguientes maneras:

- a) Por medio de absorción con aceite mineral o aceite ligero.
- b) Por compresión y refrigeración.
- c) Por absorción con carbón.
- d) Usando alguna combinación de estos métodos. Generalmente se usa una combinación de absorción a alta presión y baja temperatura.

10. La purificación puede consistir únicamente en estabilizar o fraccionar la mezcla para separar la gasolina de los hidrocarburos volátiles. Cuando se usa el sistema de absorción para la recuperación de los líquidos, antes de efectuarse la purificación debe separarse el aceite de absorción de los líquidos recuperados por medio de diferentes tipos de torres estabilizadoras.

11. Actualmente en México, de las tres plantas de absorción existentes, dos de ellas están siendo modificadas para aumentar sus capacidades en un 40 por ciento, por medio de un nuevo sistema de refrigeración y cambiando sus diseños para operación a alta presión. Próximamente se pondrá en operación una cuarta planta cuyo diseño incluye la tecnología anteriormente mencionada.

12. Obtención de materias primas petroquímicas de sistemas de refinación.

13. En la actualidad la industria petroquímica en México está adquiriendo gran importancia dentro de la economía del país, por tender a reducir considerablemente la fuga de divisas al suspender importaciones de productos petroquímicos, cuyo consumo en el país está siendo cada día más considerable, y para obtener materias primas básicas para la formación de nuevas industrias.

14. Dentro de las materias primas básicas de la petroquímica que se pueden obtener directamente de sistemas de refinación se encuentran, el etileno, el propileno, el butadieno y los aromáticos. Una de las formas de obtener estas materias es por medio de :

- a) Plantas de desintegración catalítica
- b) Por conversión de etano.
- c) Plantas extractoras de aromáticos.

15. Plantas de desintegración catalítica.

16. La función principal de una planta desintegradora catalítica es la de transformar en productos ligeros los productos pesados de la refinación. El rendimiento promedio de gasolinas es del orden de un 40 a 45 por ciento. Este proceso es económicamente posible porque disminuye el rendimiento de residuo combustible del petróleo crudo, y produce además gasolina con un índice de octano más elevado, lo que es absolutamente necesario en la actualidad para poder suministrar el octano requerido por los motores de los automóviles modernos. Este sistema de desintegración catalítica produce además, etileno, propano, propileno, butano, butileno y otros gases olefínicos que requieren de diversos sistemas de recuperación y purificación, así como de plantas adicionales para su conversión a productos comerciales.

17. En México existen en operación, tres plantas de este tipo, una cuarta se encuentra en construcción.

18. Plantas de Etileno.

19. El etileno se puede obtener recuperándolo de las fracciones gaseosas que lo contenga, tales como las que se obtienen en las plantas de desintegración catalítica, o por conversión directa del etano.

20. Plantas de Aromáticos.

21. Las plantas productoras de aromáticos están íntimamente ligadas a los sistemas de refinación, en virtud de que sus materias primas básicas son productos de la industria petrolera.

22. Los productos de estas plantas petroquímicas son: benzol, toluol, ortoxileno, meta y para-xilenos mixtos.

23. El benzol es el principal componente de los siguientes compuestos químicos: estireno, etilbenceno, dodecilbenceno, insecticidas, ciclohexano y fenol. Estos materiales, son bases para la fabricación del hule sintético, plásticos, detergentes, insecticidas, fibras de nylon y otras síntesis orgánicas.

24. El tolueno se usa para la manufactura de explosivos, para la fabricación de gasolinas de aviación y como solvente.

25. El ortoxileno es materia prima para el anhídrido ftálico que se emplea para la fabricación de pigmentos, anilinas y pinturas.

26. El para-xileno es base para el ácido tereftálico, que se emplea como insecticida y principalmente como materia prima para fibras sintéticas textiles.

27. Plantas petroquímicas en México en operación y en construcción, que producen materias primas para la fabricación de productos terminados:

28. Plantas en operación.

	<u>Lugar</u>	<u>Capacidad</u>
Planta de Azufre	Poza Rica, Ver.	140 Ton/día
Planta de Azufre	Cd. Madero, Tamps.	40 Ton/día
Planta de Azufre	Atzacotzalco, Méx.	35 Ton/día
Planta de Dodecilbenceno	Atzacotzalco, Méx.	100 Ton/día
Planta de Amoníaco	Minatitlán, Ver.	200 Ton/día
Planta de Amoníaco	Salamanca, Gto.	200 Ton/día

29. Plantas en construcción.

	<u>Lugar</u>	<u>Capacidad</u>
Planta de Etileno	Coatzacoalcos, Ver.	27 000 Ton/año
Planta de Etileno	Reynosa, Tamps.	18 000 Ton/año
Planta de Polietileno	Reynosa, Tamps.	18 000 Ton/año
Planta de Dodecilbenceno	Cd. Madero, Tamps.	18 000 Ton/año
Planta de Butadieno	Cd. Madero, Tamps.	30 000 Ton/año
Planta de Estireno	Cd. Madero, Tamps.	15 000 Ton/año

30. Plantas Petroquímicas en México que elaboran productos terminados.

31. Plantas en Operación.

Detergentes	Acetato de Vinilo
Acido Nítrico	Acido Sulfúrico
Nitrato de Amonio	Insecticidas
Poliestireno	Anhidrido Ftálico
Cloruro de Polivinilo	

32. Plantas en Construcción

Urea (Dos Plantas)	Acetato de Butilo
Fosfato de Amonio	Butanol Normal
Nylon 6	Acetato de Vinilo
Nylon 66	Acetato de Celulosa
Acetaldehido	Metanol
Cloruro de Vinilo	Fenol
Dicloruro de Etileno	Hule sintético
Cloruro de Etilo	Negro de Humo
Bromuro de Etileno	Tetraetilo de Plomo
Acido Acético	Oxido Mesitílico
Anhidrido Acético	Crotonaldehido
Acetato de Etilo	Acetona



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CONFERENCIA DE LAS NACIONES UNIDAS
SOBRE LA APLICACION DE LA CIENCIA Y LA TECNOLOGIA
EN BENEFICIO DE LAS REGIONES MENOS DESARROLLADAS

Punto del programa : A.3.1

México

POLITICAS DE DESARROLLO HIDRAULICO

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Las monografías presentadas en la Conferencia de las Naciones Unidas sobre la Aplicación de la Ciencia y la Tecnología en Beneficio de las Regiones Menos Desarrolladas constituyen documentos de trabajo de dicha Conferencia. Se publican tal como han sido presentadas por los colaboradores y los puntos de vista expresados en ellas corresponden a los colaboradores. (Véanse notas al dorso.)

NOTAS

1. Las monografías seleccionadas para las Sesiones Generales serán distribuidas en la Conferencia en los siguientes idiomas oficiales de las Naciones Unidas: español, francés, inglés y ruso.

2. Las monografías seleccionadas para las Sesiones Especiales serán distribuidas en la Conferencia únicamente en uno de los idiomas oficiales antes indicados.

3. Los resúmenes de las monografías presentadas por los colaboradores serán distribuidos en la Conferencia en los siguientes idiomas oficiales de las Naciones Unidas: español, francés, inglés y ruso.

4. No se procederá a la distribución general de las monografías y resúmenes con antelación a la Conferencia. Únicamente serán publicadas en cantidades limitadas con antelación a la Conferencia para uso exclusivo de las delegaciones de los gobiernos participantes y de otros participantes autorizados. La publicación con posterioridad a la Conferencia y la distribución general de las actas y debates de la Conferencia seguirán las prácticas de las Naciones Unidas establecidas por la Junta de Publicaciones de las Naciones Unidas.

POLITICAS DE DESARROLLO HIDRAULICO

Dirección de Ingeniería Sanitaria
Secretaría de Salubridad y Asistencia.
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Dentro de los innumerables usos que tiene el agua los más importantes son: riego, generación de energía, abastecimiento de agua a las poblaciones y aprovechamiento de las aguas servidas y de mar.

A continuación se tratará las políticas que se han seguido - en el desarrollo hidráulico de cada una de ellas.

a).- Antecedentes.-

Las obras realizadas para el aprovechamiento de los recursos hidráulicos, han experimentado un gran impulso a partir del año de 1925 a raíz y como producto de que la Revolución Mexicana alcanzó madurez y estabilidad, iniciándose en esa época la etapa constructiva de obras de carácter social entre las que cabe mencionar especialmente a la Reforma Agraria, que continuadas y sin interrupción desde entonces a la fecha, han -- permitido a nuestro país un notable progreso material.

En la época anterior a la mencionada, los beneficios que se obtenían de las pocas obras ejecutadas solo eran aprovechadas por particulares los cuales realizaban inversiones para su beneficio personal y el Gobierno Federal solo intervenía en autorizar concesiones para el uso o - empleo de los recursos.

b).- Irrigación.-

A pesar de que nuestra nación es pobre en recursos hidráulicos para desarrollar su agricultura, no obstante haber sido hasta la fecha, la ocupación predominante de nuestro pueblo, (como se verá en la monografía A.3.1.1) la principal base para un mayor desenvolvimiento de la agricultura, es la irrigación.

El gobierno Federal estableció en el año de 1926 un nuevo organismo gubernamental que se llamó Comisión Nacional de Irrigación, que - tenía por objeto desarrollar una vigorosa política de riego en el país, - Como instrumento legal, el Congreso aprobó la Ley de Irrigación de 1926, que declaraba de utilidad el riego de las propiedades agrícolas privadas, cualquiera que fuera su extensión y cultivo. Al principio se marcó como - política preferente al aprovechamiento de las aguas por medio de grandes-

obras de riego principalmente en las corrientes internacionales; posteriormente se cambió la política hacia la ejecución de obras para beneficiar fundamentalmente a los campesinos más pobres, iniciándose en ese período la construcción de obras de pequeña irrigación que sin interrupción se continúa hasta la fecha.

A partir de 1947 se creó la Secretaría de Recursos Hidráulicos, que en lo sucesivo se encargaría de todo lo relacionado con los recursos hidráulicos del país; obras de irrigación, obras de abastecimiento de agua potable, obras de alcantarillado, obras de defensa contra las inundaciones, el estudio del agua en generación de energía eléctrica y la creación y mejoramiento de vías fluviales de navegación. Con ello se trataba de que nuestro país obtuviera, de un recursos natural renovable muy escaso y muy valioso -el agua- toda la utilidad posible mediante obras de fines múltiples, estudiando en forma integral cada río.

Como consecuencia de lo anterior se crearon Comisiones de cuencas hidrológicas específicas cuya finalidad es promover el desarrollo integral y armónico de todos los recursos renovables y no renovables localizados en las cuencas de los ríos. Sus facultades, llegan a ser en algunos casos más amplias que las de la misma Secretaría de que dependen llegando a abarcar problemas muy diversos como el saneamiento del medio ambiente, vías de comunicación escuelas, creación, ampliación y mejoramiento de centros de población, medidas y disposiciones en materia agrícola, industrial y social y prevención de la contaminación de las corrientes de la cuenca.

En términos generales con la política seguida, se ha conseguido que a pesar del notable crecimiento de la población, las superficies de riego han aumentado al mismo ritmo de crecimiento, con lo cual la superficie de riego por habitante se ha mantenido constante. Sin embargo la cifra 0.12 Ha/hab que ha logrado mantenerse es muy baja si se relaciona con las que tienen otros países.

Por otra parte los rendimientos de las tierras que cuentan con riego han sido 2.5 veces mayores que en las de temporal, y como consecuencia en la actualidad se tienen rendimientos medios por hectarea más altos.

Eso ha hecho necesario planear una política con la que fundamentalmente se tiende a lograr un notable aumento en el rendimiento por hectárea, lo que puede obtenerse mejorando las técnicas agrícolas con el fin de alcanzar un mayor fruto de las inversiones hechas por el Gobierno y aumentar la superficie aprovechable mediante obras de irrigación que abran nuevas tierras al cultivo, con el fin de aumentar la superficie de riego por habitante y no únicamente mantenerla constante.

c).- Energía Eléctrica.-

La industria eléctrica comenzó a desarrollarse mediante la instalación de pequeñas plantas privadas para uso industrial y con el establecimiento de compañías de capital nacional que operaban a principios del siglo en unas cuantas ciudades. Posteriormente comenzaron a operar empresas extranjeras que debido a la creciente demanda de energía para alumbrado público, transporte urbano e industrias, crecieron rápidamente absorbiendo a las plantas independientes. Durante esta época hubo una --

gran construcción de plantas eléctricas, pero se careció de reglamentación específica y regulación, o sea que no hubo en un solo momento política de electrificación. Esta situación perduró hasta la tercera década.

Al expedirse la Ley de la Industria Eléctrica en 1933, se constituyó a ésta, en un servicio público y la prestación del servicio, un monopolio que debía ser regulado y vigilado por el Estado. Sin embargo la regulación de tarifas impidió que las ganancias privadas fueran estimadas como suficientes para provocar la inversión y la expansión eléctricas que el rápido crecimiento económico del país requería. La electrificación se detuvo en el momento en que más necesaria era para llevar a cabo el desarrollo económico del país.

Por decreto del 14 de agosto de 1937, se creó la Comisión Federal de Electricidad como un organismo del Estado encargado de organizar y dirigir un sistema nacional de energía eléctrica, al que se le otorgó preferencia en el uso de los recursos hidráulicos y facultades para vetar las concesiones cuando estas estorbaran su propio desarrollo. Con estas medidas, el desarrollo del crecimiento eléctrico se intensificó a una tasa promedio de 14% anual en los últimos 10 años. Sin embargo este incremento se logró más bien a base de plantas termoeléctricas, pasando a ocupar la generación hidroeléctrica que en 1937 representaba casi el 60% del total, un segundo lugar con 44% en 1959.

Esto debe atribuirse a la necesidad que tuvo el país de una rápida electrificación. Debido a que los aprovechamientos hidroeléctricos no pueden realizarse sin un período previo y generalmente largo de estudio, tanto del proyecto como del mercado que va a atender la nueva obra y en virtud al estancamiento sufrido por el país, no se había avanzado lo suficiente en la investigación de nuevos potenciales hidroeléctricos, se tuvo que recurrir a construir plantas termoeléctricas cuyo período de estudio y construcción es mucho más breve. Afortunadamente esa etapa parece que se está superando como lo demuestran los grandes sistemas hidroeléctricos que se están construyendo actualmente.

A pesar del gran desarrollo que en los últimos años se ha realizado en este campo, actualmente nuestra riqueza hidroeléctrica aprovechada es baja y las necesidades nacionales en la actualidad están muy por encima de la producción ya que inclusive poco más del 55% de la producción no cuenta con este vital servicio.

Si el problema en la actualidad es grande, se irá agudizando en el futuro debido al elevado crecimiento demográfico y solo una política de desarrollo integral, o sea obras planificadas de aprovechamiento de los recursos por cuencas, podrá dar la solución adecuada. La nacionalización de la industria eléctrica efectuada en 1960, dará una nueva orientación a la economía mexicana de perspectivas futuras inmejorables.

d).- Abastecimiento de agua.-

Al igual que con el aprovechamiento de los anteriores recursos hidráulicos, los Gobiernos otorgaron la debida importancia a la utilización del agua con fines de abastecimiento. Para tal fin, trabajaron en la construcción de este tipo de obras diversos organismos oficia

les e instituciones semi-oficiales y privadas, entre otras, la Dirección General de Ingeniería Sanitaria dependiente de la Secretaría de Salubridad y Asistencia pero por lo difícil de conseguir una adecuada coordinación y organización de los trabajos de los varios organismos que intervinían se obtuvo en la mayoría de los casos un gran desperdicio de recursos económicos que se tradujo en un avance lento en la ejecución de las obras.

Desde Diciembre de 1946 en que comenzó a trabajar la actual Secretaría de Recursos Hidráulicos, se declaró de utilidad pública la -- planeación, proyección, ejecución y operación de las obras de abastecimiento de agua potable y de alcantarillado, así como los trabajos relativos de planificación y zonificación en la población de la República.

En la actualidad son dos las Secretarías de Estado las que tienen a su cargo el aprovechamiento del agua para fines de abastecimiento: la Secretaría de Recursos Hidráulicos, correspondiéndole planear, -- proyectar y ejecutar las obras de abastecimiento de agua, así como los trabajos de planificación y zonificación en las poblaciones de la República cuando dichas obras o trabajos se realicen total o parcialmente -- con fondos federales, o con fondos obtenidos con aval federal. CUando dichas obras se efectúen con fondos ajenos al federal o sin su garantía, -- la acción de la Secretaría de Recursos Hidráulicos se limitará a revisar y en su caso a aprobar desde el punto de vista exclusivamente técnico, -- los proyectos respectivos y a verificar y exigir que las obras se realicen conforme a dichos proyectos aprobados.

La Secretaría de Salubridad y Asistencia a la que deberán -- ser sometidos para su consideración y aprobación en su caso, desde el -- punto de vista sanitario, todos los proyectos de obras de provisión de -- agua que realice la Federación con sus fondos o garantía, así como los -- que pretenden realizar las autoridades locales o los particulares, reglamentando las limitaciones en cuanto a los caracteres físicos, químicos y bacteriológicos de las aguas, que permitan exigir la potabilidad de las aguas en todas las obras de abastecimiento.

A pesar del gran número de obras construidas en los últimos 10 años ,el constante aumento de población origina un déficit cada vez -- mayor de poblaciones atendidas.

La población sin servicio origina grandes gastos de asistencia pública del orden de \$ 3,000 millones anuales para combatir el 21.6% de un total de 3,800.00 casos de enfermedades atribuibles a la falta de sistemas adecuados de abastecimiento de agua tanto en calidad como en -- cantidad.

i).- Política seguida por la Secretaría de Recursos Hidráulicos.-

Para la construcción de obras de abastecimiento de agua, la Secretaría de Recursos Hidráulicos aplica la Ley de Cooperación para dotación de Agua Potable a los Municipios, que dice en uno de sus artículos:

"El Gobierno Federal cooperará con las autoridades locales a la realización de las obras de agua potable mediante in-

versiones no recuperables equivalentes a la mitad de su costo en localidades de menos de 30,000 habitantes, y a un tercio en las de 30,000 o más".

Desgraciadamente los recursos económicos con que cuenta la mayoría de nuestras poblaciones, les ha impedido aportar de inmediato las cantidades que les corresponden de acuerdo con la Ley mencionada para poder aprovechar sus ventajas, destacándose dos hechos principales, resultado de lo anterior; uno que obliga a un avance lento de construcción de obras por no tenerse un número amplio de poblaciones que reúnen los requisitos de financiamiento, y otro de la necesidad por parte del Gobierno Federal de condonar a las poblaciones sus deudas en lapsos variables de años.³

Esta política fomenta también el aumento del déficit de habitantes que no tienen servicio adecuado de abastecimiento de agua.

La Secretaría de Recursos Hidráulicos ha propuesto un plan, en el cual, conocidas las necesidades de servicio a una población creciente, y estableciendo el año de 1980 como límite del período dentro del cual todas las poblaciones mayores de 100 habitantes deberán contar con abastecimiento se propone un plan de inversiones federales crecientes desde 156 millones de pesos en 1961 hasta 375 millones de pesos en 1980, continuando con la aplicación de la Ley de Cooperación antes mencionada.

De lo anterior se observan los hechos sobresalientes; la inversión federal está dentro de las posibilidades económicas del país, ya que equivalen al 5.4% del presupuesto federal actual; pero otro lado no resuelve el problema de financiamiento de la parte que le corresponde a la población al iniciar las obras o cuando más durante el tiempo que dure la construcción.

Esto último podría resolverse mediante la ejecución de las obras sin solicitar la cooperación anticipada de las comunidades pero recuperando toda la inversión mediante el cobro de tarifas adecuadas. (1)

Se reconoce el inconveniente del riesgo de no recuperar las inversiones si no se efectúan campañas intensivas de convencimiento y educación del pueblo, así como la conveniencia de contar con una legislación adecuada que garantice el cobro de las tarifas que se establezcan.

En múltiples ocasiones el usuario no puede aprovechar los servicios por falta de posibilidades para costear instalaciones intradomiciliarias y muebles adecuados para su debida utilización, por lo que es conveniente establecer fuentes de crédito de financiamiento atractivo, para estas instalaciones.

El aspecto del control de calidad del agua de los abastecimientos no deberá descuidarse y deberá incrementarse al máximo posible.

e).- Otros aprovechamientos del agua.-

Otro aspecto muy importante del aprovechamiento de los recursos hidráulicos nacionales y que ha sido poco explotado en nuestro país, los constituye la recuperación de volúmenes de agua obtenidos de las aguas negras, mediante su transformación por medio de técnicas adecuadas-

Solamente en algunos lugares se usan las aguas negras para riego, pero - sin ningún tratamiento, lo cual no es aceptable desde el punto de vista sanitario. Será una buena política incrementar la instalación de plantas de tratamiento de aguas negras, con el fin no solo de recuperar dicho líquido, sino también impedir que las mencionadas aguas negras vayan a contaminar cultivos y corrientes de agua que ya no podrán usarse sin representar un serio peligro a la salud del hombre.

Debido al avance cada vez mayor de las técnicas para aprovechar el agua de mar, no está lejano el día en que puedan aprovecharse estas aguas con fines domésticos, industriales o inclusive de irrigación y en virtud a nuestra situación geográfica que nos proporciona extensos litorales, el país quedará colocado en un lugar privilegiado para aprovechar esta inagotable fuente de recursos.

Con respecto al aprovechamiento de los ríos para navegación fluvial, las condiciones particulares de orografía del país determinan - que únicamente en las regiones costeras existen ríos importantes de corto recorrido y fuertes pendiente, por lo que únicamente son aprovechables para la navegación en los últimos kilómetros de su recorrido.

(1).-

Dirección de Ingeniería Sanitaria, S.S.A.,

Necesidades de Financiamiento para obras de provisión de agua potable,

Ingeniería Sanitaria en México, VII Congreso Interamericano de Ingeniería Sanitaria, Washington, D. C. (1962)